JOURNAL

JOURNAL

OF THE INSTITUTION OF ELECTRICAL ENGINEERS

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The Institution is not, as a body, responsible for the opinions expressed in the *Journal*, unless it is stated that an article or a letter officially represents the Council's views.

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INITIAL RESPONSE

SO FAR AS WE CAN JUDGE AT THE TIME OF WRITING, and so far as it is right to generalize, members of The Institution like the first two issues of the *Journal*. Many letters and messages about them have reached Savoy Place, and we should like to thank all those who have troubled to give their opinions. It is perhaps remarkable, and surely something that those in the Papers Committees of the last two years may feel proud of, that, without any exception at all, the letters and messages contain congratulations, and 95% of them include no criticism. The following extracts illustrate their tenor:

"I was amazed at the wonderful metamorphosis of our *Journal* this morning when I received my copy. The cover is better than anything I have seen, either here or in the U.S.A., and the typography and layout are really first rate. Please accept my sincere congratulations to all concerned in this noble effort."

"Congratulations on No. 1 of the new series of The Institution *Journal*. I think you have managed to combine the various elements in a most satisfactory manner and I look forward to reading future numbers."

"As one of the younger members of The Institution, I should like to record my appreciation of the new layout of the *Journal*. This has been transformed into an eminently readable and interesting publication, instead of being somewhat dry."

"I should like to express my appreciation of the first issue of the new *Journal* of The Institution. I consider the layout, type and contents a very marked improvement in the standard of presentation. I shall be grateful if you will convey my congratulations to all concerned in this new venture and not least to those responsible for the very fine cover."

"A few days ago I received my personal copy of the *Journal* —No. 1 of the new series; and I should like to congratulate you and your colleagues upon a first-class metamorphosis. I like the cover, the format, and the typography; although I've no doubt that some further experiments will later be made in the 'display faces.' "

"May I take this opportunity of offering my sincere congratulations on the issue of the new series of the *Journal*. 'Freshly cooked and on a new dish' is most descriptive of this new series, and it follows therefore that it is more appetizing. The format is excellent and most attractive."

"I am in my late 70's and live alone in an isolated house in an isolated district, and the new *Journal* is a 'boon and blessing.' I must confess that in its old form I found it rather dull; so many of its pages were on subjects beyond my interests. . . . So far as I am concerned the new *Journal* stands a very good chance of joining the 'second group' referred to in 'Metamorphosis.' "

"May I . . . pass to you my congratulations and appreciation for the form in which the new *Journal* now appears—without exception, all the members I have met are exceedingly enthusiastic and appreciative of this new production."

"Earlier this month I received the February number of the new *Journal*. May I add my applause to that you will already have received. The layout and content is both bright and attractive. (In lighter vein—this is not altogether a joy since my four-year-old son is fascinated by the cover and some of the diagrams to the extent that I have had some difficulty in preserving it for myself.)"

This trumpet-blowing is not intended to mask the effect of the few criticial opinions that we have received —and received with gratitude, for, genial though congratulations are, criticism, if constructive, is more useful in planning the *Journal* month by month. It will be more useful also to the Papers Committee when they come to review the first few issues as a whole. So far the volume of criticism has not been large enough to show whether the few points made are straws in the wind of a substantial part of the membership, or only indications of isolated breezes that few others support.

Probably the cover design has received more cold wind than any other feature, but it has also won some enthusiastic admirers. It has, we believe, succeeded in its main object of "getting the *Journal* talked about," for, inherently, it is something that most people either firmly like or dislike. Even those who are Laodicean in their feeling for it are apt to use it as a convenient source of banter; they may read the legend on the y-axis of a graph without a thought of discomfort, but they complain of acute cervical pain on glancing at the *Journal* cover. Another point of design which has no appeal to

one or two correspondents is the unusual placing of single-column headings on right-hand pages (as on pages 1, 9, 13, etc., of the January issue), and it can certainly be argued that this artifice makes some slight sacrifice of clarity on the altar of appearance. However, without further comment let some of this criticism speak for itself:

"I feel that I must write to congratulate you on the new *Journal*; it's a vast improvement on the old. The only thing I don't like is the colour of the cover. The Institution colours are blue and gold, so could we not have a blue cover with gold letters (or yellow if gold is too expensive)? If we must have red then can we not (holding a Royal Charter) have the royal scarlet?"

"From a cursory inspection, the new *Journal* appears to be attractive; I like the bold presentation of its contents. I do not like, however:

1. The front cover. I find the staring white background of the coat of arms distracting and the vertical arrangement of the Institution's title out of keeping with the dignity of the *Journal*.
2. I dislike emphatically the omission of capital letters from place names and feel that 'Savoy Place' appearing as 'savoy place' on page 62 is again undignified."

"In general, it is a delight to see a professional publication become aware that, in addition to presenting good information, it should take care to dress itself up attractively so that readers will feel urged to read it. . . . The fact that I should, however, like to criticize, means only that the layout has become good enough to be worth criticizing. First of all (and understandably, for the new layout must be a great shock to many older readers) do I detect a slight lack of courage? The front cover is startling—you did not lose courage there, as you knew that it is normal for covers to be startling. But inside, there is a falling off. It becomes what I may call conventional-modern layout and no more. The heads and subheads are too light—timorous, even. They may be worlds better than heavy banner headlines. But often I find a head is lost in the general mass of print. . . . I am sorry to see you suffer from the fear of white spaces, the desire to fill exactly a given space with print. Many of the main heads could be improved, not merely by increasing the size of typeface, but also by surrounding them in more whiteness. . . . It is, I say, a delight to see a new editorial policy from the I.E.E., but I believe it has been a little too finicky and not sufficiently courageous. I hope therefore that my letter can help you realize that your readers will wish your new policy to continue and mature."

In addition, a few useful suggestions for improving the content of the *Journal* have been made. One member writes:

"May I, however, take this opportunity of first complimenting you on the new *Journal*, and suggesting that in the near future space might be allocated to a brief article on the general question of earthing, with particular stress on the danger of indiscriminate earthing of neutral points and conductors."

We should be very glad to have some further views from members. There may be some who felt doubtful about the first issue, and who have been awaiting its successors before making up their minds; others with strong feelings may have, for one reason or another, not expressed them; again, one swallow does not make a summer, and some members may have had second thoughts about the opinions they gave two months ago. Criticism, appreciation and suggestions—all three will be welcome, and they will not be filed away unnoticed. The greater the number of members who give their opinions, the better the *Journal* can fulfil its purpose.

ENGINEERING APPOINTMENTS

How the P.E.A.B. can Serve

You may be thinking, for many possible reasons, of seeking a fresh job, or, if you are an employer yourself, of taking on some additional engineering staff. You have probably heard of the Professional Engineers Appointments Bureau (P.E.A.B.), but you may never have used it, because you have been uncertain whether it can help you and what kind of service it gives. This article tells you about these things, and it should give you enough knowledge to decide whether the Bureau can assist you. The Registrar will, of course, be glad to reply to any questions about the work of the P.E.A.B. that are left unanswered in your mind. Perhaps, in case you are not a Corporate Member of The Institution, it would be well to emphasize here that the P.E.A.B. is open to all members of the three major engineering Institutions, and, of course, to any employer who is seeking engineers.

THE P.E.A.B. started in 1945 as a co-operative enterprise by The Institutions of Civil, of Mechanical, and of Electrical Engineers, to provide assistance to their members on all matters concerned with employment, and to give advice on any problem affecting their careers. The Bureau is a separate incorporated body governed by a Board whose members are appointed by the Councils of the three Institutions, and is a non-profit-making organization deriving its income from fees charged where successful placings are made. Registration with the Bureau is open to all members of The Institution, and every type of electrical engineering vacancy appropriate to members is notified by employers—from practical training schemes for Students and Graduates to senior executive appointments for Corporate Members both at home and oversea.

Throughout the nine years that the Bureau has been operating, it has built up a strong link with employers and has established itself as a recognized source from which engineers can be obtained. This reputation can be maintained only if those members seeking a change of employment are prepared to make use of the Bureau by registering at the appropriate time. For some time the service it provides has not been used so much by members of The Institution as by members of the sister Institutions. Consequently, with fewer available applicants, employers notifying vacancies are not being given the choice of suitable electrical engineers that was previously possible. There is a danger that this will lead to fewer notifications of vacancies, with the possible development of a vicious circle; and although the Bureau is at present providing excellent service to electrical engineers and their employers, the possible difficulties ahead can be removed only by an increase in the number of registrations.

Registration

In order to register, a member should approach the Registrar for an application form, the purpose of which is not only to list his qualifications and experience, but also to determine the kind of electrical engineering post he desires, with its preferred location, and the minimum salary he is prepared to accept. Wherever practicable a personal interview will be arranged and these details can then be confidentially discussed and amplified where necessary. This allows the Bureau to pass on its knowledge of the current employment situation to applicants and thus ensures a better appreciation by both the Bureau and the applicant of the possibilities open to him. The personal knowledge the Bureau gains of individual candidates proves valuable in discussing their particulars with visiting employers and has been instrumental in obtaining interviews for engineers whose experience is not adequately covered by an application form. Similarly, employers welcome the opportunity of being able to discuss in detail their special requirements at an interview.

Any employer having an appropriate vacancy to fill is invited to supply the following details: (*a*) type of post; (*b*) age range; (*c*) salary; (*d*) location; (*e*) experience and qualifications desired; and (*f*) other information likely to assist in selecting suitable candidates.

Advantages of the Bureau

Some of the advantages to members using the Bureau include the special experience and technique of the Registrar and his staff in ensuring that applications are directed where they are most likely to be fruitful. Many employers have stated their appreciation of the service, which has often produced a successful candidate when wide advertising has failed. The Bureau enjoys good relations with most of the larger industrial companies, and it can frequently obtain a post for an engineer on the strength of his record, where no specific vacancy exists, because of its intimate knowledge of firms' general requirements for long-term projects. Many vacancies for senior executives are confidential, and the Bureau can often introduce both parties successfully through its knowledge of the employer's special conditions, which could not be given in an advertisement.

Cases of Difficulty

Unfortunately, although a large number of vacancies are notified, there is always the possibility that only a small proportion will be appropriate to the engineers available. This can be seen by the demand at present for light-current engineers—a demand that is large compared with the small number of engineers available with adequate training and experience. Again, the Bureau is not always able to offer the service which might be expected, as the following examples illustrate. If an engineer's presentation of his experience and qualifications is not sufficiently informative, and a personal interview not practicable, this may lead to a false assessment of the application. Where the minimum salary desired is based upon experience accumulated in a specialist field and a change from this field is desired, it is somewhat difficult to equate these requirements to the salary level offered by employers who are prepared to give the experience sought. Some posts cannot be filled because of the location of the employment. As many members of The Institution are not British subjects, the question of nationality can present difficulties, especially where firms are engaged on defence contracts. But these examples are exceptional, and most employers and applicants can be sure of a service that will be of real help to them.

More than an Employment Agency

Many members are unaware that the Bureau exists, despite the periodical notices inserted in the *Journal*, and not infrequently applicants state that they heard of the Bureau only through colleagues who had been successfully placed as a result of registration. Whilst it is no part of the Bureau's service to create vacuums by attracting engineers away from their existing posts, it is obvious that those who have decided to change should have as wide a choice of vacancies as possible, and conversely that employers with vacancies to fill should have a reasonable field of likely candidates. The Bureau aims to become the recognized clearing house for engineers seeking new posts and for employers seeking new engineering staff, but as the above paragraphs have tried to show, the Bureau is more than an employment agency. It will be clear to all that the efficiency at which the Bureau operates increases with the number of registrations on both sides. Employers and employed alike can help their fellow members and the well-being of the electrical engineering industry by registering with the Bureau now, if they have any engineering employment difficulties.

Journal I.E.E., March 1955

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

'Golden Jubilee Meeting' at Philadelphia, 1st–16th September, 1954

A Note by **J. ECCLES, C.B.E., B.Sc.,** *President*

IT was fitting that the Fiftieth Anniversary Celebration of the International Electrotechnical Commission should have taken place in the United States, for it was at St. Louis in 1904 that the Committee of the Chamber of Delegates of the International Electrical Congress recommended that steps should be taken to secure the co-operation of the technical societies of the world in the appointment of a representative commission to consider the standardization of the "nomenclature and ratings of electrical apparatus and machinery." This led to the formation of the International Electrotechnical Commission.

The I.E.C. has since grown into a body of immense international prestige, and now it is the world forum at which the important matter of scientific standardization is debated and progressed. An index of its scope is that the Jubilee Meeting was attended by 800 delegates from 20 countries. No fewer than 48 technical committees each held several sessions; all reported progress towards international agreement on the matters being discussed and several formulated programmes for future investigations.

However, it is not the purpose of this note to discuss, in detail, the findings of the experts, but rather to record one delegate's general impressions of the meeting as a whole.

To be able to assess justly the place and purpose of standardization, it is of importance to recall that, throughout the past 50 years, science has been on the march, and pioneers have been disappearing over the horizon on a new quest often before a scientific idea or practice has had time to settle in. Yesterday's basis for standardization has been undermined by to-day's discoveries and by to-morrow's hopes, and there may have been an understandable tendency for countries or even groups of scientists not to admit the need for standardization or, at best, to set up those standards which seemed to suit their own requirements, without too much thought for the desirability of international agreement.

No one would wish to hamper the pioneer in his search for new knowledge or in originality of concept and expression, but there is so much that is common ground and only requires clarification and definition to be acceptable as a common basis by all countries. There is great gain in being quite certain that, when scientists and engineers use a scientific term or quantity, it has the same meaning and value all over the world. On a more commercial plane, it is of considerable benefit to international trade if sizes and ratings of plant and machinery and voltages and systems can be agreed and adhered to.

At the Jubilee Meeting there was a noticeable advance in the views previously expressed in some countries. There was general agreement amongst the speakers at the public functions that, behind the battlefield and, indeed, in all but the frontier of knowledge there was need for consolidation and organization of the conquered territory. This was stressed on several occasions at the Meeting, and it was heartening to hear prominent American industrialists come down heavily on the side of standardization when they spoke at the official banquet.

No praise can be too high for the manner in which the Meeting was organized. The American genius for planning was evident everywhere and the execution was simplicity itself. The hospitality was on a most generous scale, and the technical and social visits added much to the pleasure of the delegates and to the opportunities for getting to know each other better.

A high-light in this respect was the visit to Longwood Gardens, where, after a sumptuous evening meal, we enjoyed an outdoor concert by the choir of the Hampton Institute (under the ever-present threat of an unrealized thunderstorm), and thereafter witnessed a most artistic display of man-made illumination in colour—the flood-lighting of the extensive fountains.

The visit to Washington was another social high-light, and no one could have failed to be impressed by this well-planned capital city with its White House, Capitol Building and Pentagon, and its monuments to famous Presidents—Washington, Jefferson and Lincoln. A little less regular than those of New York, its wide streets and avenues add dignity to the large Government buildings, shops and hotels, whilst its squares, parks and gardens compare favourably with those of any city of the Old World. Government hospitality at the Statler, and a message of encouragement to all people of good-will from Mr. Harold Stassen, Director of Foreign Operations Administration, made a lasting impression on all the delegates privileged to be present.

Next year's meeting is to be held in London, and preparations are being made by the British Standards Institution to ensure that it will be both fruitful and—within the limits of our resources—pleasant.

Journal I.E.E., March 1955

The Progress of 50c/s Railway Electrification in France

Electric Traction on the Valenciennes–Thionville Line

W. J. A. SYKES, A.M.I.Mech.E.

In May, 1954, two papers by M. M. Garreau and M. F. Nouvion on the French 50c/s electrified railways were read before an absorbed and crowded meeting of The Institution, and the article that appears below amplifies and follows up the information given then. At that time the regular service on the Valenciennes–Thionville line, which is electrified with a single-phase 50c/s a.c. supply, had not yet begun; and both the authors of the papers and speakers in the discussion looked forward keenly to the day when the French 50c/s system could be assessed operationally and economically in the light of practical experience. The time for full assessment has not yet arrived, but in the course of his article Mr. W. J. A. Sykes, of British Railways, gives a few first-fruits of five months' operating experience on the Valenciennes–Thionville line, which many members will read with great interest. We may note that at present the pros and cons of the possible future use of 50c/s traction in Britain have not been resolved. This does not change the national need to start large-scale electrification in Britain rapidly, and, as the Chairman of the Traction Technical Committee of The Institution emphasized in his article in the January Journal, three committees have recommended that the 1 500-volt d.c. overhead system should be used in Britain. Delay in proceeding with the first stage of a British electrification scheme, such as that now before Parliament, in order to assess fully this outstanding French engineering achievement, would, we believe, cause damage to the economy of Britain far greater than any eventual benefit that might arise from a reduction in electrification costs.

THE success attending the recent inauguration of electric traction on the Valenciennes–Thionville line of the Société Nationale des Chemins de Fer Français (S.N.C.F.), and the extensive further projects now in hand, once more call attention to the way in which the possibilities of commercial-frequency alternating current appear to have gripped the minds of French railway engineers, and to have led them to advocate this form of traction on a scale which has made its advance something of a triumphal march rather than the steady and cautious progress to be expected of a new electrification technique.

For a correct understanding of the way in which this has come about it is necessary to go back to the last years of the Second World War; for although there have been published in Britain some descriptions[1,2] of the rolling stock, fixed equipment, and signalling of the first sections of the 50c/s scheme in North-Eastern France, no attention appears to have been paid to the striking and even dramatic manner in which this form of traction was presented to the imaginations of French railway engineers.

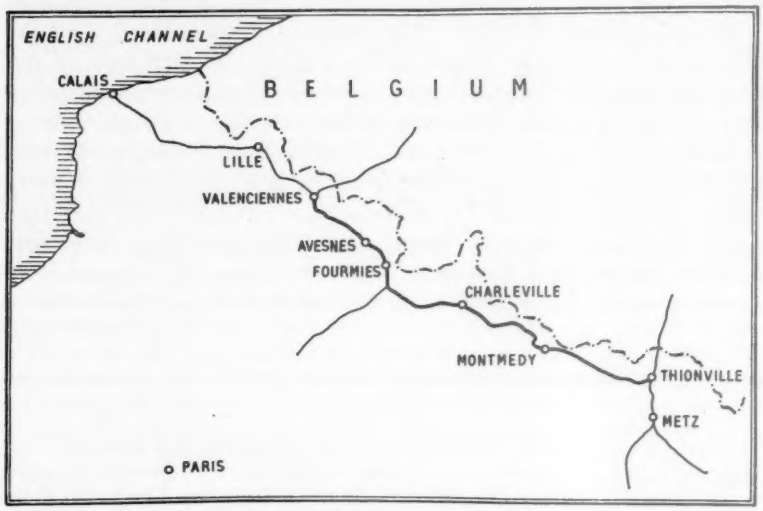
During the German occupation of France, M. Louis Armand, then Traction Engineer of the S.N.C.F.'s western region, made a careful study of the 50c/s electrification experiments of the German railways on their Höllenthal line. Subsequently, on receiving warning from his friends in the Railway Resistance Movement that his arrest was imminent, he devoted his last hours of liberty to setting out his knowledge and ideas on 50c/s traction in a document addressed to his General Manager; this document M. Pierre Tissier, late Chairman of the S.N.C.F. Board of Management, later termed "in every sense an engineer's will."

After the liberation, a party of French engineers investigated the German project and decided that there was a case for constructing a trial section of 50c/s electrification in France. They were unable to interest the large French manufacturing firms in the construction of 50c/s traction motors, since these firms considered them technically impracticable; but with the determination which has never ceased to animate French electric traction engineers, they procured a badly damaged 16⅔c/s motor-coach found at the German Zeppelin works, and with single-phase commutator motors constructed by small private firms, produced the first 50c/s motor-coach to run on French lines. This coach later became No. Z9053, which ran successfully on the 50c/s experimental lines in Savoy.

After the satisfactory result of the Savoy project, the S.N.C.F. decided on the extensive programme of 50c/s electrification in N.E. France briefly outlined below. Throughout its triumphant progress the encouragement of M. Armand, now President of the S.N.C.F., has never ceased to inspire the engineers responsible.

Future traction engineers may have good reason to regard the development of h.v. a.c. electrification as

marking as important an advance in traction technology as did the outmoding of the rotary convertor by the remote-controlled mercury-arc rectifier on d.c. systems. Not only is it possible to space the substations at wide intervals, from 30 to 50 miles apart, but the great flexibility in location enables most of the railway substations to be housed in substations of the national Grid system near the line. Thus the costly railway h.v. cable transmission system that is required for d.c. systems is eliminated, and the substations themselves become simple transformer stations, with the major part of the equipment of the outdoor type, and only the control-gear housed in a very small hut.



1 *Sketch-map of the Valenciennes–Thionville line*

Inauguration of N.E. France Electrification

On the 5th August, 1954, the first section of the Valenciennes–Thionville electrification (Fig. 1) was opened for traffic between Valenciennes and Charleville—84 miles of sharply profiled track with long 1-in-100 gradients. A short description will now be given of the motive power and fixed equipment at present in operation.

Locomotive No.	Date in service	Type of traction motor	Mileage to 30.11.54	Train weights, metric tons	
				Average	Max.
BB12001	17.7.54	Ignitron-fed. D.C.	54 624	725	1 400
BB12002	23.10.54		12 487		
BB13001	13.7.54	Series. Single-phase a.c.	52 800	660	900
BB13002	30.9.54		19 835		
CC14101	29.7.54	D.C. motors fed by a.c./d.c. convertor	42 024	1 800	2 040
CC14102	9.10.54		19 226		

Six locomotives of various types are in service, as shown in the Table; their principal features have already been described in the Institution papers by M. Garreau and M. Nouvion.[3]

It will be noted that the average daily mileage since entry into service is 300–400, which is remarkably high for a route only 84 miles in length. All the maximum loads given in the Table have been started successfully on 1-in-100 up-gradients, and the CC locomotives in particular have shown convincingly that their capabilities in the freight field are in advance of any other locomotive so far produced in France.

On the 17th December, 1954, exactly five months after delivery, locomotive No. BB12001 completed 100 000 km, and by December 27th No. BB13001 had run a similar distance. As from December, 1954, the rate of delivery has been increased to 7–8 locomotives a month. The first of a further series of 20 freight locomotives with variable-frequency 3-phase motors was delivered in January of this year.

To date, the service record of these locomotives has been extremely good. There have been no troubles of a kind which might indicate that either design or technical principles were in any way at fault; the minor defects that have occurred are the type of troubles that appear in any new project. Heavy overhaul costs are not yet available on account of the limited mileage so far run; but the day-to-day maintenance time amounting to an average of one day out of service for every 50 days in service is certainly not excessive. Two types of locomotive in use on the line are shown in Figs. 2 and 3.

Substations

A typical joint S.N.C.F./E.D.F. (Électricité de France) substation and feeders is shown in Fig. 4. These sub-

2 *B_0–B_0 4-axle locomotive with single-phase series motors*

stations are of two types: "end substations" equipped with single-phase transformers, and "intermediate substations" provided with Scott-connected transformers, giving two independent single-phase supplies, and avoiding excessive unbalance; installed transformer capacity in each substation varies from 5000 to 10000 kVA. The substations on the present Valenciennes-Thionville scheme (which is really the first stage of the very much larger project mentioned later) are remotely controlled from a control room at Charleville by means of a quad channel incorporated in the long-distance telephone cable, which, under electrification, replaces the former pole-lines. Track sectioning and paralleling cabins are provided at mid-sections.

3 *C_0–C_0 locomotive with a.c./d.c. convertor set hauling a heavy train of high-capacity wagons*

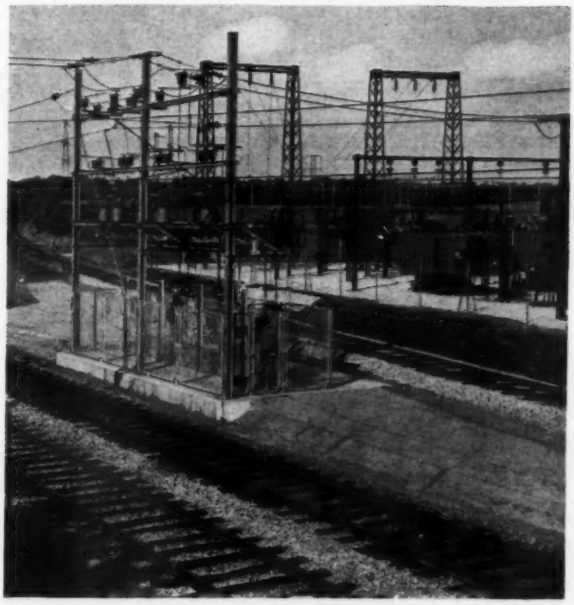
The Overhead Equipment

The contact system has been described as the "lightest on earth," and when considered in conjunction with the heavy train loadings the whole project well merits M. Armand's saying: "Under the lightest catenary on earth run the heaviest trains in Europe." The nominal operating voltage is 25 kV, the voltage limits being 27·5 kV and 19 kV, with drops of short duration to 17·5 kV. The frequency variation is from 51 c/s to 48 c/s.

On running lines the overhead system consists of one 65 mm² bronze carrier cable, and one 107 mm² contact wire, giving a combined copper cross-section of 147 mm² approximately. The sidings have a 30 mm² stainless-steel carrier, or a 43 mm² galvanized cable, and one 107 mm² contact wire. Fig. 5 shows a typical stretch of main-line track, in which the lightness of overhead construction and the good visibility afforded to drivers are well in evidence. It will be noted that all suspension insulators are well clear of any direct fouling by steam locomotives, in accordance with best modern practice. The normal height of the contact wire on open track is 5·5 m; under structures the contact surface may drop to 4·65 m at the highest temperatures, but in all instances it clears the international loading gauge of 4·28 m by an adequate margin.

Minimum electrical clearance between live conductors and earth varies from 370 mm for mixed steam and electric operation with long-distance obstructions to 220 mm for electric operation only with short-distance obstructions. However, the whole question of clearances has such an important influence on the total cost of the civil engineering work of any such electrification that the matter is the subject of continuous study by both French and German railway engineers, and it seems likely that in the future these minimum clearances will be reduced.

4 *Typical joint S.N.C.F./E.D.F. traction substation at Fourmies with track-feeder switchgear in foreground*



Insulator quality is of particular importance in such a system; the characteristics of the suspension insulators are as follows:

Minimum dry flashover voltage..	150kV
Flashover voltage in rain ..	100kV, used vertically
	125kV, used horizontally
Minimum breakdown voltage:	
1/50 positive wave	270kV
1/50 negative wave	300kV

5 *Section of double track with independent catenary suspension*

The overhead supports are normally formed of standard broad-flanged beams spaced at intervals varying from 63m on straight track to 31·5m on curves of 250m radius. Foundations for masts are excavated mechanically.

An interesting feature of this type of high-voltage a.c. system is that bonding of the running rails for the return traction current is not normally required. Tests have shown that most of the traction current leaves the rails within a short distance of one substation and does not reappear until within a short distance of the next. In very long sections the traction current in the centre is practically zero, though there is a longitudinal voltage induced in the track which gives rise to a current in the running rails when current is flowing in the contact system.

For safety reasons all the track-work in stations is bonded together and solidly earthed. The whole question of track voltage conditions is somewhat complicated, and has been explained in considerable detail elsewhere by S.N.C.F. engineers.[1]

Signalling Track-Circuits

To avoid interference troubles from the 50c/s traction supply a frequency of 83⅓c/s has been chosen for the distribution to signalling installations, and these are fed from convertor sets housed in the substations. Since the cost and size of impedance bonds vary inversely with the frequency, tests have been made with the highest frequencies possible for track-circuit purposes, and a frequency of 1 000c/s has been selected for extended trial. This frequency is produced by valve oscillator sets fed from a 115-volt 50c/s auxiliary supply, and an installation using this principle is working successfully at Avesnes.

Future Policy

The results already obtained have encouraged the S.N.C.F. to extend the Valenciennes–Thionville electrification southwards for a total of 240km to Réding and Basle, and to electrify at 50c/s the lines from Dôle to Vallorbe and from Frasne to Pontarlier further south—an additional 117km. These extensions, when combined with the extension of the existing 1 500-volt electrification from Dijon to Dôle, will enable through electric haulage to be obtained from Paris to Berne.[4]

The Basle–Réding section is due to be commissioned early in 1957; Strasbourg–Basle will follow later the same year.

For the 50c/s portion of these extensions the following additional electric locomotives have been ordered:

37 C_0–C_0 six-axle type, with a.c./d.c. convertors.
9 B_0–B_0 four-axle type, with a.c. series motors.
9 B_0–B_0 four-axle type, with ignitron-fed d.c. motors.

It is interesting to note that it will be possible, under electrification, to convert the whole of the double-tracked section between Dôle and Frasne to single-line working (apart from a small section in the centre necessary to work traffic coming in from other lines). A considerable reduction in expenses, both of first cost and of track-maintenance charges, will thus be achieved, and it will be interesting to see to what extent such a policy can be applied with advantage in further h.v. a.c. electrification schemes.

The saving in coal at 6 250 francs/metric-ton at the locomotive tender, against an annual consumption of electricity of 120×10^6kWh at 5·5 francs/kWh, is estimated to amount to 235 000 tons per annum, and the net monetary saving to amount to 805×10^6 francs (1952 prices). The return on the total cost of works is estimated to be 8·4%.

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The History of Electrical Engineering

2. TOWARDS THE NEW LIGHT

In this second article in his series on the History of Electrical Engineering, Mr. MacKechnie Jarvis continues his account of the important steps in the revelation of electrical science, including the experiments of Davy, Faraday, and Arago. Increasing knowledge of electricity leads on to the development of the arc lamp, which, apart from the electric telegraph, was the first manifestation of electrical engineering to make real impact on the public.

C. MACKECHNIE JARVIS, *Member*

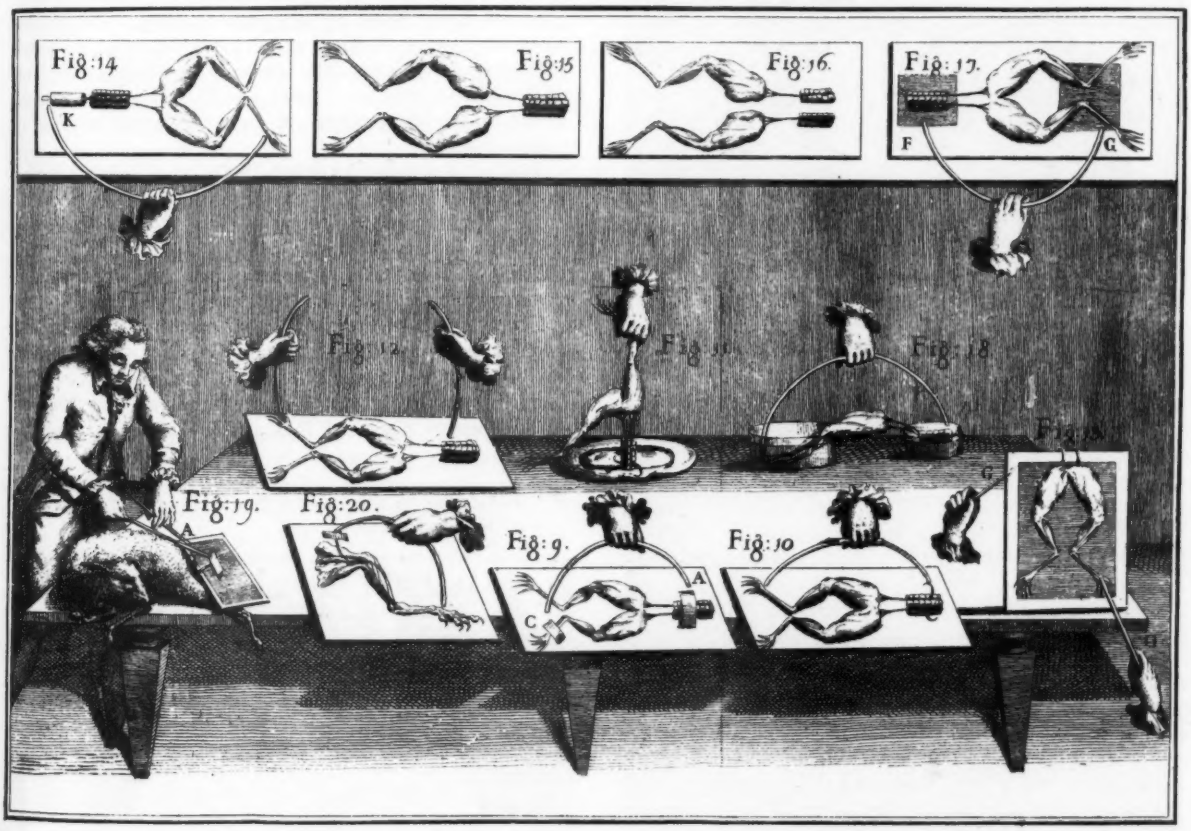
THE invention of the voltaic pile, or battery, by Alessandro Volta in 1796, referred to in the first article in this series, was the practical interpretation of Professor Galvani's classic experiments with the legs of frogs. It gave enormous impetus to the study of electricity, and at the same time raised an obvious question of identity. Was the "electric fluid" generated in the pile the same as that already known from the influence machine? This question was resolved by the joint work of Dr. van Marum and Professor C. H. Pfaff, who communicated their results in a paper to the Haarlem Society of Sciences in May, 1801, and these supported the hypothesis that electricity, however produced, had a common identity.

Volta's pile consisted of alternate discs of copper or silver and zinc, separated by cloth or paper soaked in an acid electrolyte. Volta later constructed his renowned *couronne de tasses*, a battery in which the cells consisted of cups containing strips of silver and zinc and a saline solution. The carbon and zinc combination originated in 1795, when Dr. C. W. Wells, F.R.S. (1757–1817), demonstrated that charcoal and zinc could be used to produce voltaic action.

The voltaic pile in its various primitive forms took its place as part of the normal equipment of the electrical laboratory, side by side with the frictional or influence machines, which by now were being made in large sizes.

1 *The experiments of Professor Aloysius Galvani*

This plate is reproduced from Volta's copy of the rare book by Galvani (in the Silvanus Thompson Collection in the Library of The Institution) entitled *De viribus electricitatis* . . . (Modena, 1792).



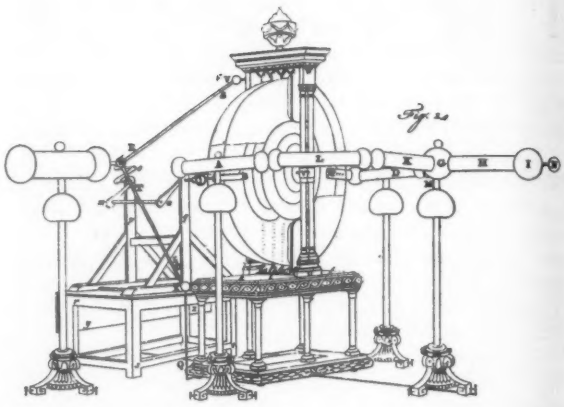
Dr. van Marum was, for example, using (*c.* 1790) a machine with glass plates of diameter 65 inches in conjunction with Leyden jars whose coated surfaces aggregated 225 square feet. This machine was designed with the assistance of John Cuthbertson, an Englishman resident in Holland.

Electrochemistry

Dr. J. Priestley, F.R.S. (1733–1804), was among the first to investigate at all thoroughly the chemical effects of an electric current, and around 1772 Henry Cavendish, F.R.S. (1731–1810), carried out further work in the same field on a quantitative basis, with both liquids and gases. He synthesized water by means of a spark discharge through a mixture of hydrogen and air, but missed the discovery of the electrical decomposition of water, which awaited the researches of the Dutch chemists, van Troostwyk and Deimann; in 1789 they repeated and extended the experiments of Cavendish. The chemical effect of spark discharges through atmospheric air had been fully investigated by Cavendish, but in 1785 van Marum, using oxygen instead, discovered a gas with a distinct smell, described by Cavallo as "electrified air," and later renamed "ozone" by the chemist Schonbein, when he investigated its properties in 1840. The source of electricity for all these experiments was the frictional machine. In the year 1800, however, William Nicholson (1753–1815) and Dr. Anthony Carlisle (1769–1840) achieved the electrolysis of water with the use of a voltaic battery.

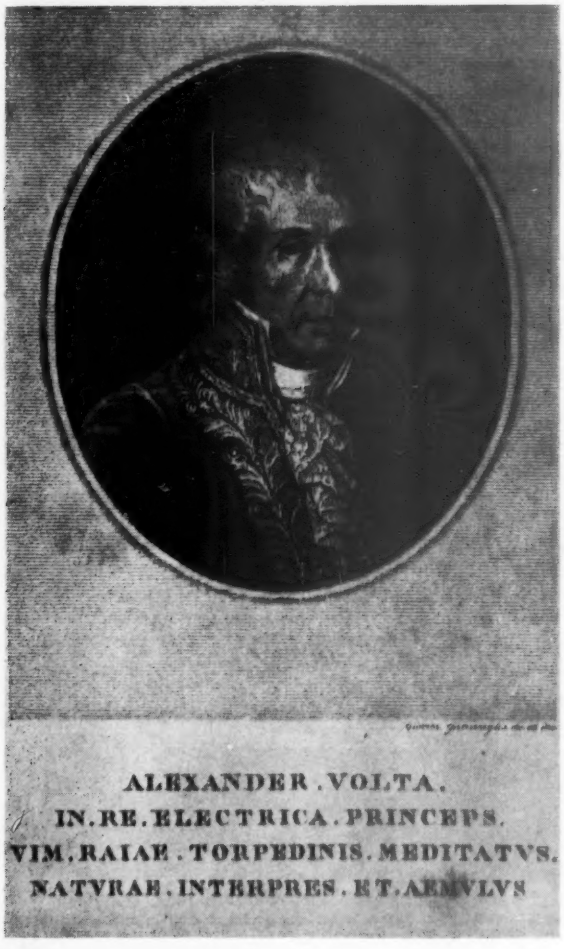
William Cruikshanks (1746–1800), who undertook the construction of the first of the large batteries for the Royal Institution, deserves the credit for producing a workable battery from the primitive piles then in use. He also discovered the colour change produced by the passage of current through certain solutions, e.g. litmus.

From then on, the voltaic battery was used almost exclusively, and with its aid, metallic silver was obtained in 1801 by J. W. Ritter (1776–1810) by electrolysis of a solution of silver salts. The well-known researches of Sir Humphry Davy, F.R.S. (1778–1829), in electro-

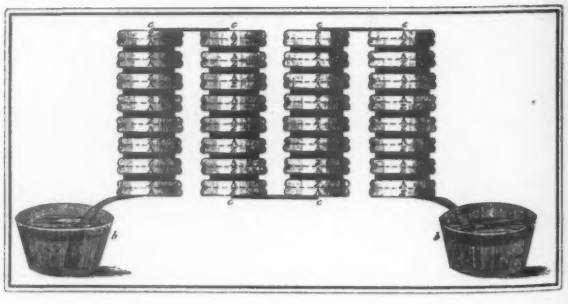


2 *Dr. van Marum's large influence machine at the Teylerian Institution, Haarlem, 1790*

3 *Alessandro Volta (1745–1827) at the age of 69*



4 *Volta's Pile, as illustrated in the Philosophical Transactions of the Royal Society, 1800*



chemistry also date from 1801, in which year he contributed his first paper to the Royal Society.

Davy, a Cornishman, came to London at the age of 23 to take up an appointment at the Royal Institution as Director of the Laboratory. Working at first with Cruikshanks's voltaic battery of 500 plates, the most powerful then in existence, he carried out many experiments on the electrolysis of alkalies and alkaline earths, and in 1807 he isolated the metallic elements, potassium and sodium, and later, four other elements, barium, strontium, calcium and magnesium. In 1808 the 500-plate battery had become unserviceable and was replaced by another of larger construction, possessing 2 000 pairs of zinc and copper plates, but contrary to expectations very few new discoveries were made with the larger battery, although it obviously gave greater scope to experiments with the electric arc. Davy was justly regarded as the greatest chemist of his age, and yet his most important "discovery" was probably that of a young man who became his assistant and was many years later his successor at the Royal Institution—Michael Faraday, F.R.S. (1791–1867).

The early galvanic batteries suffered from the evils of polarization when in use, and wasting of the metal plates when idle. Many attempts were made to find remedies, and numerous cells were devised during the ensuing half-century. Thus, in 1830, Sturgeon (1783–1850) adopted the surface amalgamation of the zinc (a practice which continues to-day), the treated metal behaving in a manner similar to that of chemically pure zinc in regard to its resistance to corrosion by an acid electrolyte.

The Daniell two-fluid cell was the first of the constant-e.m.f. batteries, and was due to Professor J. F. Daniell (1790–1845) of King's College, London, who published an account of it in the *Philosophical Transactions* in 1836. Without doubt it proved to be the most popular of its class, and with certain improvements continued to be used for many years, especially for telegraphic and signalling purposes. The first notable modification to the Daniell cell was that due to John Fuller, who in 1853 substituted a solution of zinc sulphate for the sulphuric acid formerly used in the inner cell. In this form it was constructed as a 12-cell unit for the telegraphic service, and known as the Fuller trough battery. It continued in use until the brothers J. C. and G. Fuller in 1875 patented the mercury-bichromate cell, producing two volts; three of these cells were said, on account of lower internal resistance, to equal in service a 10-cell Daniell battery, and to operate at a fraction of the cost.

Among the first recorded practical applications of electrochemistry is that by L. V. Brugnatelli, who in 1802 employed electrical methods to gold-plate some medallions. Henry Bessemer, F.R.S. (1813–98), employed the electrical process for copper-plating lead ornaments in 1834. Although the process must have been well known at that time, it was not until 1840 that patents were granted, first to Joseph Shore for the electro-deposition of copper and nickel and then to G. B. and H. Elkington for the electro-deposition of various metals.

5 *Sir Humphry Davy, F.R.S. (1778–1829)*
An engraving reproduced by courtesy of the Royal Institution.

In 1841 the subject of electroplating received authoritative treatment from Alfred Smee in "Elements of Electro-metallurgy," a book which was for years a standard work of reference.[1] Smee (1818–78) improved the primary cell, and in 1840 introduced a mechanical arrangement to counteract polarization, which does not appear to have become a serious rival to the Daniell cell for electroplating purposes.

The electrotype process in printing *per se* seems to have originated with T. Spencer, *c.* 1837, after the introduction of the Daniell cell. The process was described to the Liverpool Polytechnic Society in a paper read in September, 1839, but in 1836 W. De La Rue had drawn attention to the fact that the copper deposited on the copper container of the cell when stripped off "has the counterpart of every scratch of the plate on which it has been deposited." Spencer was granted a patent for his invention in 1840. Independently, in 1839, C. J. Jordan published elsewhere details of a process, which became known commercially as Jordantype, and later as electrotype.

Before leaving the subject of electrochemistry, reference should be made to the contributions of Michael Faraday. In the early years of the 19th century the theory of attraction and repulsion of molecules towards the plates of a cell had been advanced, it being supposed

that the "poles" of a battery possessed a power of attraction comparable with that of the poles of a magnet. Certain workers, e.g. Theodore von Grotthus (1785–1822), maintained the two-fluid theory of resinous and vitreous electricity issuing respectively from negative and positive poles, as originally proposed in connection with influence machines by C. F. de C. Dufay of Paris in 1733.

Faraday did not accept this theory, and finding that the term "pole" gave rise in the mind of his contemporaries to much confusion, wisely sought advice on nomenclature from the mathematician and philosopher, W. Whewell of Trinity College, Cambridge. In 1834, at Whewell's suggestion, Faraday adopted "electrode" instead, defining it as "a . . . surface whether of air, water, metal, or any other body which bounds the extent of the decomposing matter in the direction of the current." Faraday proposed the terms "anode" and "cathode" to differentiate between the two electrodes. The particles involved in the electrochemical process he designated "ions," using the prefixes "an-" and "cat-" or "cath-" as before, and further proposed the terms "electrolysis" and "electrolyte"; all of these are, of course, in use to-day.

The Electromagnet and its Progeny

Although the compound term "electro-magnetismus" appears in a book published in 1641,[2] it is, of course, used in a sense very different from "electromagnetism" to-day.

The discovery of the magnetic effect of an electric current is due to H. C. Oersted (1770–1851), who in 1820 published in Copenhagen a small pamphlet in Latin, in which he announced the result of his observations of the movement of a magnetic needle when placed near a conductor carrying a current from a voltaic battery. Oersted recognized the existence of a magnetic field surrounding the conductor, and his discovery earned him the Copley Medal of the Royal Society.

It seems quite probable that this effect was known to Davy, who had for years been experimenting with heavy currents, drawn from the battery at the Royal Institution, for it is on record that in 1820 he noticed iron filings adhering to the wires connected to the terminals of his apparatus. The experiment of Oersted was repeated in many parts of Europe, and in September, 1820, A. M. Ampère (1775–1836) postulated the law relating the position of the magnetic needle to the direction of the current in the conductor; this was followed by other papers explaining the theory of the electromagnet, which he demonstrated in Paris by means of experiments that have become classic.

Michael Faraday, working at the Royal Institution in 1821, confirmed Oersted's experiments, and reasoned that, if the poles of a magnetic needle tended to move round a fixed conductor, the converse should also be true. To this end he devised suitable apparatus, with which he was able to demonstrate both forms of rotation towards the end of 1821.

In 1825 W. Sturgeon exhibited at the Royal Society of Arts a soft-iron electromagnet, for which he was awarded a prize. As a result of this he is often credited with being the first to produce such a device, but there is little doubt that he was anticipated by D. F. J. Arago (1786–1853), Ampère, and perhaps others.

Faraday's interests covered an extremely wide field, and it is not surprising that during the 10 years following 1821 he found little time for further electrical experiments. It must be remembered that his early work under the tutelage of Davy was largely concerned with chemistry and electrochemistry. He carried out much valuable work on the chemistry of organic compounds during the decade 1821–31 as well as conducting his researches into optical glass. Nevertheless, he seems to have borne in mind throughout this period the note entered in his commonplace book in 1822: "Convert magnetism into electricity." This he achieved within a relatively short time when he again renewed his experiments in August, 1831. Faraday was aware of the observation made in 1824 by Arago, who noted that the needle of a small compass enclosed in a casing of copper, when disturbed, came to rest after a few obviously damped oscillations. Arago, having checked the copper and found it free from iron, reasoned that some unknown force was responsible, and argued that, if a stationary plate of copper could bring a needle to rest, it ought to be possible to detect movement in a stationary magnetized needle placed near a moving plate of copper.

In 1825 Arago made the further experiment of rotating a flat copper disc beneath a magnetic needle screened from the disc to obviate windage, and found as he had anticipated that the needle would follow the rotating disc. Faraday had made isolated unsuccessful attempts to produce electricity from magnetism, but in 1831 started afresh in a new direction. Using two coils wound one on top of the other on a wooden former, he performed the classic experiment of passing a current through one and detecting by means of a galvanometer the current induced in the other. This experiment he repeated in a variety of ways, sometimes with two coils, sometimes with a single coil and a magnet or a bar of soft iron, until he was satisfied that relative motion was responsible for the linkage between magnetism and electricity. Thus he established in the summer of 1831 the principle of electromagnetic induction. The well-known experiment of rotating a copper disc between the poles of the Royal Society's large permanent magnet,* and collecting current therefrom, followed shortly afterwards.

In a paper to the Royal Society read on the 24th November, 1831, Faraday used the concept of lines or tubes of magnetic force, and referred to the use of iron filings to demonstrate the existence of the field of a magnet. Faraday for the time being did not feel inclined to probe the matter further, and turned to research in other fields. Others, however, took up the work with renewed vigour, and by 1833 several inventors, including Christie and Sturgeon, had produced small electric motors, which, although primitive, served to demonstrate the possibility of what lay in that direction.

* At the "House of Mr. Christie."

6 *Michael Faraday, F.R.S. (1791–1867)*
A painting by H. W. Pickersgill, 1830, reproduced by courtesy of the Royal Institution.

Some other Electrical Pioneers

Sir William Snow Harris, F.R.S. (1781–1867), a surgeon, became interested in frictional electricity and made great improvements in the technique of lightning conductors. Following the suggestion of Benjamin Cook (*c.* 1811), he undertook to design protection for the contemporary wooden ship on behalf of the Admiralty, and devised means of letting the conductors into the spars and masts, carrying these through the ship to an earth plate fixed below. Apparently the lightning conductor on one vessel was taken through the powder magazine, to the consternation of the Board of Admiralty.

Harris wrote several papers on the subject of magnetic forces, especially those of repulsion, which he investigated (*c.* 1825) with his bifilar balance. Harris was awarded the Copley Medal of the Royal Society, but appears to have been unable to accommodate his outlook to the development of voltaic electricity. As late as 1861 he contributed to the Royal Society a paper on Bennett's discharger for the plate machine, and in 1864 one on laws of electrical distribution based on "unit jars."

To his contemporary, Sir David Brewster (1781–1868), is due the credit for having made students in Britain familiar with continental progress at a time when local societies and journals were tending to replace the *Philosophical Transactions*, which had formerly been the exclusive international medium for the exchange of scientific views. Brewster's scientific papers number some three hundred; he wrote on many subjects, including the nature and origin of electric light (electrostatically produced), and following the original researches of Hauy (1743–1822), discovered the pyro-electric properties of the diamond and other gem stones.

Georg Simon Ohm (1787–1854), sometime Professor of Physics at Munich, published in 1826 a paper in which his fundamental law was first stated. Its importance was not immediately recognized, and it is certain that Faraday had no knowledge of it until several years later. Ohm was immediately attacked by the German philosopher Hegel and his school for having suggested a theory which did not form part of a complete philosophic system, and he was compelled to resign his appointment as teacher of mathematics at Cologne.

An English version of the theory did not appear until 1841, in which year Ohm was awarded the Copley Medal of the Royal Society.

Post tenebras lux

Apart from the somewhat transitory discharges from influence machines or the weak glow produced within glass cylinders when excited during rotation, the first source of constant electric illumination was obtained by Davy, using "well-calcined carbon . . . for the production of the spark . . . between the extremities of Signor Volta's pile" and described in a letter dated the 22nd September, 1800. Two years later, Davy wrote: "when instead of metals, pieces of well-calcined carbon were employed, the spark was still larger and of a clear white." Similar references occur in scientific papers and textbooks of the period (e.g. Cuthbertson; see Reference 11 of the first article).

Although brilliant displays of the light of the carbon arc were given in the lecture theatre of the Royal Institution and elsewhere from time to time, any exploitation of it that approached success had to await the work of W. E. Staite (1809–54) and W. Petrie (1821–1904). Staite's experiments began in 1834, and from 1840 onwards they were directed to the improvement of the electric arc as a means of illumination; but it was not until 1846 that he was able to produce a steady light "more or less continuous." The principal difficulties encountered were those of obtaining carbon in a suitable form, absence of satisfactory means for regulating the arc, and inadequacy of the batteries from which the lamps were supplied. British Patents for the purification of carbon were granted to Jabez Church in 1845, and to W. Greener and W. E. Staite in 1846.

The possibilities of the filament lamp became obvious when towards the end of the 18th century successive experimenters rendered metallic wires incandescent by the discharge of batteries of Leyden jars. It was soon realized that such luminous spirals rapidly oxidized, and attempts were made by, amongst others, W. De La Rue (*c.* 1820) and W. R. Grove, F.R.S. (in 1840), to employ filaments of platinum wire in partially evacuated bulbs. These lamps proved to have a short life owing partly to

the imperfection of the vacuum and partly to the narrow margin between the fusion point of platinum and the temperature at which it glows.

Staite experimented along similar lines, using a platinum–iridium-alloy filament in a lamp which he exhibited at a lecture on electrical illumination in Sunderland before the Literary and Philosophical Society on the 25th October, 1847, but this lamp possessed the shortcomings of its predecessors. It was this lecture which young Joseph Swan* attended and was thereby started on a quest that many years later brought him fame and fortune. Swan tells us something of the conditions prevailing in the early part of the 19th century, which in these days of abundant light are difficult to appreciate:

> The days of my youth extend backwards to the dark ages, for I was born when the rushlight, the tallow dip or solitary blaze of the hearth were the common means of indoor lighting. . . . In the chambers of the great, the wax candle, or exceptionally a multiplicity of them, relieved the gloom on state occasions; but as a rule, the common people, wanting the inducement of indoor brightness such as we enjoy, went to bed soon after sunset.

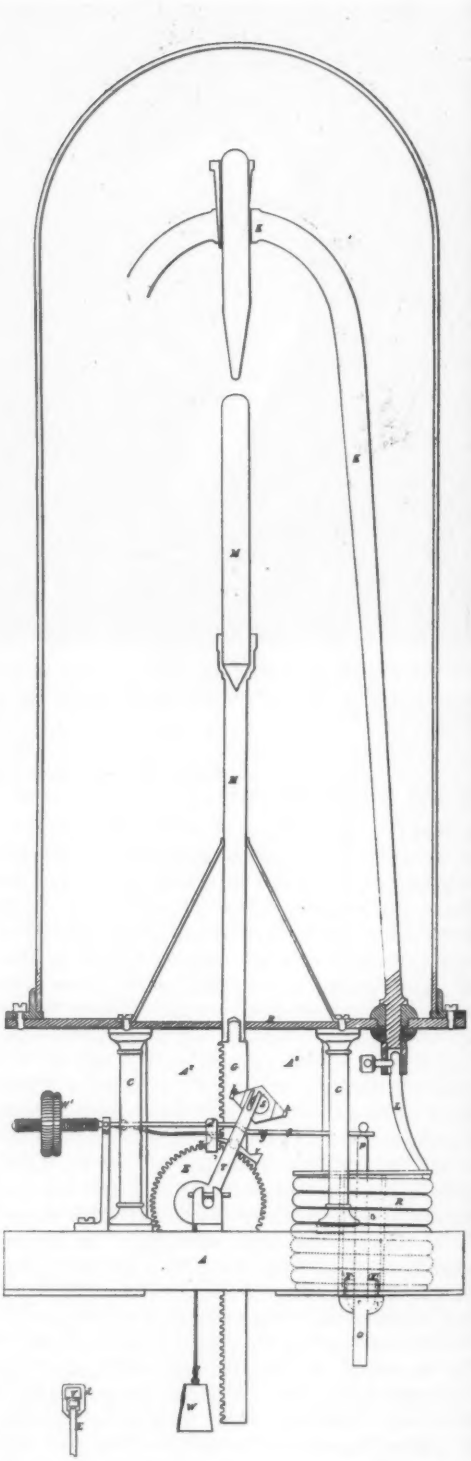
The principal exhibit of the evening was Staite's arc lamp, to which further reference will be made. Although they were not the first to patent an arc lamp, it may justly be claimed that Staite and Petrie produced the first successful apparatus.

Reference is sometimes made to the first patent granted in England for an arc lamp, to F. de Moleyns of Cheltenham (No. 9053 of 1841). This consisted of two coiled platinum elements, normally held apart but brought together by an adjusting screw and rendered incandescent by current from a battery. Powdered carbon was allowed to fall by gravity so as to impinge on the incandescent elements, forming a luminous mass or flame of high intensity. The apparatus was enclosed in an evacuated bulb, and despite the claims of the inventor, possessed obvious disadvantages; it aroused relatively little interest.

The next patent for electric lamps was granted in the name of King, an agent acting for J. W. Starr of Cincinatti, United States, in 1845. Starr's lamp consisted of strips of platinum foil or of carbon, rendered incandescent by the passage of "galvanic or other electric current suitably regulated." The elements were required to attain the highest temperature they would "bear without fusing." No details of the regulating mechanism are given, and as nothing further was heard of the lamp, it may be assumed that it was unsuccessful.

Staite's lamp of 1846 was fitted with a fixed-rate clockwork mechanism for advancing the carbons and was therefore open to objection. The 1847 lamp embodied his "pyrometric principle" of control for the carbon electrodes, whereby the effect of the heat radiated from the arc (which increases as the arc lengthens owing to the consumption of the carbon) is employed via a copper wire to control the operation of the mechanism regulating the distance between the carbons. This principle was later used by Altman in his arc lamp of 1848 and some 30

* Sir Joseph Swan, F.R.S. (1828–1914).



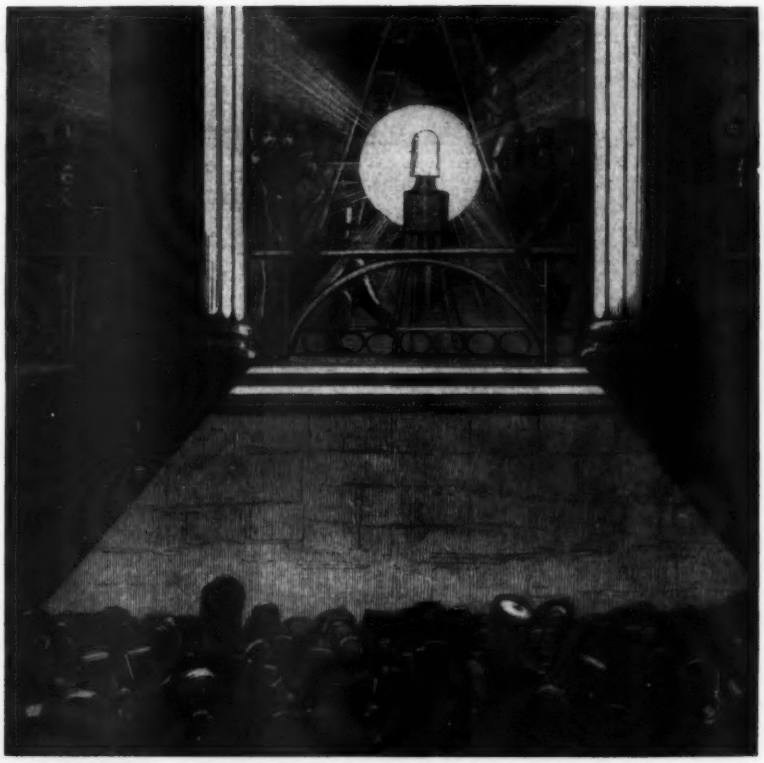
7 *The arc lamp of Staite and Petrie, 1848*

years afterwards by Siemens and Edison. The 1847 lamp was seen by a number of persons at private demonstrations given at Staite's Clerkenwell laboratory and was shown publicly in London at the request of the Directors of the Royal Polytechnic Institute.

Staite and Petrie met in London for the first time in 1847, Petrie, a consulting engineer, having been engaged by certain financial interests to give a report on the lamp. The defects in the regulating apparatus became evident and Petrie designed a solenoid-pattern apparatus, which by arrangement was patented in the name of Staite in 1847 and 1848, and jointly in 1849.

After the Sunderland lecture on the 25th October, 1847, Staite's arc lamp provided the illumination for the annual ball of the Literary and Philosophical Society at the Athenaeum Assembly Room on the next evening.

An improved lamp was used publicly in London for the first time on the 12th October, 1848, at a conversazione of the Western Literary Institution in Leicester Square, and in the same year at the Hanover Square Concert Rooms. According to a contemporary account[4] the latter meeting was attended "by artists, scientists, engineers, gas directors, proprietors of patent lights of every kind, and a multitude of intelligent and respectable persons."



8 *Flood-lighting of the National Gallery, 28th November, 1848*
A contemporary illustration reproduced by courtesy of *The Illustrated London News.*

The enthusiasm displayed towards the new light was great. Staite and Petrie gave many demonstrations between 1849 and 1853, and the subject became a popular one with lecturers generally. On the 28th November, 1848, the portico of the National Gallery was lit by arc lamps and attracted an enormous crowd. Graphic accounts of this appeared in the *Morning Chronicle* dated November 29th and in *The Illustrated London News* dated December 9th.

In 1853 the brothers Mayhew (Henry Mayhew later became the first editor of *Punch*) were lecturing and demonstrating with the aid of an arc lamp of their own design, probably without regulating apparatus. This lamp was shown in Jersey and Guernsey in March, 1849. The *Jersey Times* dated March 9th quotes one of the brothers as follows: "My brother and I are confident that we shall eventually be able to turn charcoal into diamonds. I have already formed crystals from powdered charcoal but they had not the shape or solidity of diamond. Still, I hope to overcome the difficulty. . . ."

On the Continent, Foucault was making arc lamps and he claimed priority for the invention of the first practical lamp. This claim was contested by Staite and Petrie, in whose favour the question was decided by the Committee of the Academie des Sciences.

Staite put forward various estimates of the cost of operating his arc lamps, which are not without interest. Thus the total cost of the light was stated "not to exceed a penny per 100 wax candle power per hour, or about one twelfth of the price of gas." It must be borne in mind that in saying this Staite was comparing the arc light with gas burned at a fish-tail burner, many years before the invention of the Welsbach mantle in 1886.

Each lamp was estimated to provide 900 wax candle power, and "the heat given out is disproportionate to the light emitted, and is estimated not to exceed that of a common Argand [oil] burner." The lamp consumed approximately half an inch of carbon per hour. Elsewhere it is stated that the batteries used one-third of a pound of zinc per 100 candle-power per hour.

Staite and Petrie gave further demonstrations in London from the north tower of Hungerford Bridge. For 14 consecutive evenings the new light was displayed for periods of three hours in May and June, 1849.

On the 6th February, 1850, Staite and Petrie read a paper on "Improvements in the Electric Light" before the Royal Society of Arts, and in May, 1850, Staite was

again in Sunderland demonstrating to the Commissioners of the River Wear the use of his lamp for dock and harbour light applications, with excellent results. At Manchester on August 7th, the two collaborators staged a large-scale demonstration at the country house of the Mayor at Buile Hill, which aroused the customary interest, and finally the new light was shown to Queen Victoria on her visit to Worsley Hall, the seat of the Earl of Ellesmere, on the 10th October, 1851.

The apparent success of the arc light had prompted the setting up of a committee to examine its suitability for general purposes, including those of navigation. After months of deliberation an adverse report was presented, in which the cost of battery maintenance was strongly criticized; as a result the many schemes for the wider use of the new light then under consideration were abandoned.

There is a reference in the *Transactions of the Royal Society of Arts* to the lighting of the promenades on the occasion of the third Exhibition of the Society[5] in 1849, when electrical apparatus comprising arc lamps fed from chemical batteries was hired from the Patent Electric Light Co. This company was floated in 1846–47 with an authorized capital of a quarter of a million pounds. Staite, who was prominent in the venture, is understood to have lost the bulk of his private means when the company failed about 1850.

Thus although the inventors overcame two of the three major difficulties in their path (see page 149), they were finally defeated by the limitations of the primary cells which they were compelled to use as a source of power, and with the collapse of the Patent Electric Light Co. the arc lamp was for a time again reduced to its former status of a laboratory spectacle.

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The Measurements Section discuss

BOREHOLE INSTRUMENTS

On the 2nd November, 1954, Mr. P. Threadgold opened a discussion on "Boreholes—Instrumentation for Measuring at Depth" at a meeting of the Measurements Section. A summary of his remarks and the subsequent discussion appears below.

MR. P. THREADGOLD began by saying that a borehole might be 2 miles deep and inclined at 5°, or even more, from the vertical; its diameter of, say, 20in at the surface might decrease to about 4in at the bottom, and the inclined surfaces of the bore would be rough.

Instruments might be lowered at speeds up to 4m.p.h., and might encounter temperatures exceeding 200°F, while the oil, water, gas, or drilling "mud" in the borehole could exert a hydrostatic pressure of as much as 15 000lb/in^2 at the bottom of the hole. Measurements of a number of parameters might be required, and, in addition, instruments were used to assess geological characteristics in terms of the radioactivity and the electrical resistivity of formations.

Depth is usually measured by having mechanical or magnetic markers on the line and paying it out through an appropriate counting device. Instruments to measure borehole inclination use the vertical and the magnetic north as reference directions, displacements therefrom being registered as a change of inductance or of capacitance and then transmitted to the surface electrically by cable. Diameters are measured by lowering a mechanical internal calliper, and again the readings are converted to electrical quantities and passed up by cable.

A borehole-logging truck during field operations

Fluid pressures are measured accurately by a Bourdon tube element in conjunction with a clockwork recorder; this forms a reliable self-contained unit, which has not so far been superseded by electrical devices. The maximum-type thermometer suffices for most measurements of borehole-fluid temperatures, but if a continuous log with depth is required, the electrical resistance-bridge type is used. The electrical resistivity of the borehole fluid is recorded by lowering a 2- or 4-electrode system, the latter being unaffected by the cable resistance. The spatial arrangement of the electrodes should not significantly impede the relative movement of the fluid. Some form of spinner with a counting device is generally used to indicate changes in fluid flow rate, in order to locate strata from which fluid is entering the bore.

Mr. Threadgold said that geological information was

deduced from natural radioactivity, measured by a Geiger–Müller counter with integrating circuits; a short integration time-constant expedited measurements at successive depths, but might prevent registration of a thin bed. When the borehole diameter and the level of natural radioactivity were known, induced radioactivity would furnish data for the calculation of the porosity of a stratum.

The nature and extent of the fluid content of such strata—whether gas, oil, water, or a mixture—are deduced by calculation from the electrical resistivity of the whole formation, which is usually determined by introducing current from two electrodes and measuring potential difference by two others; the calculations employ this figure in conjunction with the other parameters. Ideally, all values should be determined simultaneously, but the need to send driving current down to the instruments, and the limited number of ways afforded by a manageable cable, make it difficult to bring up more than three simultaneous measurements.

The number of unknowns in the calculations necessitates the collection of families of readings, obtained by varying the electrode spacings and thereby sampling various volumes of the formation. Although additional circuits are undesirable, there is a tendency to use electrode systems having focused current paths, to obtain greater accuracy and definition.

Interaction between the borehole fluid and any water in the formation sets up electrochemically a measurable direct potential, from which the resistivity of the water can be calculated. In addition, the hydrostatic pressure of the drilling mud, which is often increased by chemical loading, causes it to invade the porous formation. The resistivity of the zone thus invaded is evaluated by micro-resistivity measurements, using electrodes about 1in apart in contact with the borehole wall but guarded from the fluid.

In this way, knowledge of the measured resistivities of the borehole mud filtrate, and of the porous zone completely saturated by the mud filtrate, enables the free pore volume to be calculated.

Mr. Threadgold stated that the resistance which this volume would show, were it entirely filled with the water of known resistivity, could be calculated. The observed resistivity of the porous zone was therefore a measure of the extent to which it was occupied by water, the remaining space being occupied by oil or gas.

Rapid geological observations at successive depths were claimed for a continuously operating geophone employing the magnetostrictive effect.

In the discussion which followed, further details of radioactivity measurements were given. In uranium prospecting, γ-ray logging is usual in the shallower and smaller boreholes, the probe being passed down inside the drill. The use of transistors and cold-cathode valves obviates a power core in the cable.

Observations within a mine can be made over distances not exceeding 300ft, using sealed probes supplied from mining-type nickel-cadmium batteries. Scintillation counters were preferred to Geiger–Müller tubes, but they introduce design difficulties due to the undesirable size of existing photo-multipliers, although a speaker observed that British manufacturers now offer one of $1\frac{1}{8}$in diameter.

One member noted an experimental scheme which uses a fast-neutron source and logs the resultant slow neutrons from the formation, with an alternative means of registration by segregating the neutron-induced γ-ray emissions according to their energy levels. The resistance of rock can be too high to permit of its use as an earth return for counting circuits. For deep boreholes, a single-core cable with an armoured conducting exterior is suitable; a specimen was shown with an overall diameter of 0·115in, a weight of 22·75lb per 1 000 feet, and a minimum breaking load of 900lb. A probe, demountable into four parts and in a tube of $\frac{3}{4}$in diameter and about 4ft long, was also shown. This contains a Geiger–Müller counter, with halogen-quenched low-voltage tubes to simplify the power supply. The recording unit at the surface uses a 50μA movement to direct a spark on to heat-sensitive paper passing over a knife-edge.

A speaker inquired whether electrical methods might be adopted in geothermal investigations. At present, temperatures of 450°F in a turbulent and corrosive mixture of liquids and solids are measured by a 2in-diameter bathythermograph comprising a bimetal element recording on a smoked slide. Thermocouple methods are precluded by lack of cable of sufficient strength or length. Subsequently Mr. Threadgold suggested the possibility of making scanning measurements to a diameter of 40ft with supersonic callipers.

The velocity method of investigation was described: spurious vibrations are first eliminated by stopping the drilling rig; sound is then released at the surface, and the velocity of its transmission measured at successive strata. An experimental version uses a piezo-electrical transmitter and receiver at either end of a 5ft probe, and measures the time for transmission of a pulse. There is also an electrically-driven percussive system having two receivers 10ft apart; their output is registered on a cathode-ray tube, which is continuously photographed as the borehole is explored.

A member outlined the development of a borehole gravimeter. This instrument adopts a vertical position despite borehole inclination, and measures gravitational acceleration by a spring-balance system which is vacuum-insulated against the effects of heat. The electrical dissipation of the operating mechanism must be restricted to 10 watts, making an efficient motor desirable.

A speaker testified to the willingness of British manufacturers to collaborate with users, despite the long period needed for the development of borehole instruments and the limited market, and he believed that, although American manufacturers predominate in the market at present, British products can be increasingly successful in the future.

Journal I.E.E., March 1955

Fifty Glowing Years

THE JUBILEE OF THE THERMIONIC VALVE

The Celebration in London

WHEN a historian of, perhaps, A.D. 2250 comes to write an account of technological development in our present century, he will, if he has done his research well, lay decided emphasis on the invention of the thermionic valve by John Ambrose Fleming in November, 1904. We, who have grown up or grown old with the evolution of this amazing electrical device of a hundred-and-one applications, can appreciate its impact on the 20th-century world only as a temporary stage-hand appreciates a swiftly moving play; he is mixed up in it, but some of the action is lost to him and he does not know how the play will end, or what impressions the audience will carry away. Nevertheless a moment's reflection will give us, even to-day, a smattering of the historian's picture of the electrical development of the first half of the 20th century—development, especially in light-current engineering, of giddy speed, with the thermionic valve as one of the leading runners in an excited rush of invention and application. The breeze from the land of semi-conductors may now be fanning us with cool efficiency and we may wonder about the future of the thermionic valve, but few, if any, of us would predict no future for it; so versatile a component has become one of the primary bricks of electrical engineering structures. Whatever the future holds, the thermionic valve has an illustrious past and present, and this was the emphasis of last autumn's Celebration of the first 50 years of Fleming's invention.

The diode with which Fleming succeeded in rectifying h.f. currents in 1904

As so many inventions, it was a simple one; it uncovered no pearl from the hidden treasure of scientific knowledge. But a flash of genius was needed to conjure up the two-electrode valve as the outcome of the Edison effect, which had been discovered in 1883. Fleming's invention may be viewed as a natural sequel to a long series of brilliant discoveries in classical physics, made by many scientists during the second half of the 19th century, but, more properly, it should be regarded as one of the first steps in the development of radio and electronic engineering. Fleming was an engineer in outlook and his invention has been the seed from which a large and supremely important family of electronic components has grown. He was either unlucky or unforeseeing (according to one's attitude) in that he failed to produce the three-electrode valve, so skilfully invented by Lee de Forest, but his is the achievement of having made the fundamental device. To-day he would, in the words of Sir Gordon Radley, "have been thrilled by the very large family that has sprung from that original and simple diode".

The Celebration of the Jubilee was held in two places, the Electrical Engineering Laboratories of University College, London, where Fleming was Professor of Electrical Engineering when he made his invention, and the Institution building. University College and The Institution planned their commemorative events separately, but there was a friendly liaison between

them, and to those who were invited to attend the Jubilee in both places, it appeared as a single celebration of Fleming's achievement. The Celebration took place on the 16th November, 1954, exactly 50 years after Fleming's application for a patent for his valve, and it was honoured by the presence of the Lord President of the Council, the Marquess of Salisbury, both in Gower Street and at Savoy Place. This account is concerned mainly with The Institution's part in the Celebration.

The proceedings began in the morning at University College, where guests were received by the Provost, Dr. B. Ifor Evans, before touring a varied and well-arranged exhibition in the Electrical Engineering Laboratories of the College. This included many exhibits connected historically with Fleming's invention: his original valve patent specification; instruments used by him; collections of original Edison lamps used by Fleming and of early Fleming valves; correspondence with Marconi; and the room in which the work on the famous invention was carried out. Also on view were valves and other developments resulting from the diode, together with examples of the electronic research—particularly in the science of microwaves—that is taking place to-day in the laboratories, under the direction of the Pender Professor of Electrical Engineering, Dr. H. E. M. Barlow. Another side to the exhibition illustrated some of Fleming's work in fields such as electrical measurements and transformers, and his work as a teacher, including a reproduction of the original drawing of his famous mnemonic—the Fleming Right-Hand Rule. (What an error he made in devising a Left-Hand Rule as well—an unparalleled source of confusion to students.) Not the least interesting exhibits were those that drew a portrait of Fleming the man; he painted, climbed, and was deeply interested in religion, writing one or two theological books, as well as his well-known books on electrical subjects such as "Fifty Years of Electricity." Apart from the many working demonstrations to illustrate current research in the laboratories, there were a few "live" historical exhibits, such as a Marconi magnetic detector, and, connected in a simple circuit, an early Fleming diode receiving a B.B.C. programme, to which the visitor could listen through headphones.

ERECTED TO COMMEMORATE THE LIFE AND WORK OF
SIR AMBROSE FLEMING
A FORMER STUDENT AND PROFESSOR OF THE COLLEGE AND THE INVENTOR OF THE THERMIONIC VALVE. THIS PLAQUE WHICH ADJOINS THE LABORATORY IN WHICH THE VALVE WAS FIRST APPLIED TO DETECT HIGH FREQUENCY WAVES, WAS UNVEILED ON THE 16TH NOVEMBER 1954, THE 50TH ANNIVERSARY OF THE FILING OF THE ORIGINAL PATENT SPECIFICATION.

In the early afternoon Lord Salisbury unveiled, in the presence of Lady Fleming, a plaque in University College to the memory of Sir Ambrose Fleming, which is placed in the passage leading to the Electrical Engineering Laboratories. The plaque is of oak with gold lettering, and the wording on it is given above.

The Lord President of the Council makes his opening address in the Lecture Theatre of The Institution
The portrait of Sir Ambrose Fleming by Sir William Orpen is behind Lord Salisbury.

So on to Savoy Place, where The Institution's part in the Celebration began after lunch. The programme consisted of an opening address by Lord Salisbury, three lectures, by Professor G. W. O. Howe, Sir Edward Appleton, and Dr. J. Thomson, on Fleming and thermionic valves, and an exhibition of valve development. The President was in the chair for the meeting, which began in the Lecture Theatre at 2.30 p.m. The Theatre was quite filled by members and guests, and an overflow meeting was arranged in the Faraday Room, to which the speeches and lectures were relayed. There were two lectures in the afternoon, and these were followed by an interval for tea and inspection of the valve exhibition; the third lecture was given at 5.30 p.m.

In the course of his opening speech, the Lord President of the Council, the Most Honourable the Marquess of Salisbury, K.G., P.C., said:

"It is my privilege this afternoon to open the series of lectures which are being given here to celebrate the jubilee of the discovery of the thermionic valve by Sir Ambrose Fleming. If I may say so, I am very happy to see so large and distinguished an audience here to-day, and that is surely right, for this occasion is certainly one the significance of which we should none of us underestimate.

"It was said to me the other day, that the age of the inventor, in the old sense of the term, was over, and that it had been succeeded by the age of the scientist. I cannot personally accept such a wide generalization as that, for, after all, it implies that all the inventors of the past were either pure cranks or blind experimentalists, whereas I suppose it would be fair to assume that the men who invented such startling innovations as the wheel, the bridle, the button and the fork, did come to their conclusions as a result of some definite process of observation and reasoning rather similar to that which is the basis of all science. However, it is no doubt equally true that, whereas those early discoverers were venturing into largely unknown territory, the more recent ones have been advancing for the most part from a solid base of ascertained fact.

"To that more modern school I think we shall all agree that Sir Ambrose Fleming certainly belonged. His work, as we know, followed a trail which had already been blazed by Edison, Thomson, Richardson and others, and he followed to that extent where they had already preceded him. At the same time, it is certainly true that his inspiration carried him far beyond what they had discovered, and he has, I think, long been accepted as the man who can fairly claim credit for being the scientist who first discovered the thermionic valve; and by doing so he conferred yet further lustre on British science.

"It is, I am afraid, a hard fact—as I know from my comparatively short experience of the work of Research Councils—that our country, which is so pre-eminent in the field of pure science, has often not maintained the lead in the practical application of those discoveries, and there other countries have tended to catch us up and in some respects to outstrip us. The thermionic valve is no exception to that rule; but we can at least say that we pointed the way they have so successfully followed.

"The thermionic valve, I imagine, has already inaugurated in one sense a new era in the world: wireless transmission, television and radar, all have already widened to a marked extent the boundaries of human experience. In this country to-day, within the period of 50 years which we are considering, there is hardly a home, however humble, that has not a radio set, and vast numbers of our fellow-citizens are now enjoying the even greater advantages of television. Modern civilized man now regards it as a severe deprivation if he does not have the best acting, the best music, the best sport and the latest news transmitted to him in a tiny fraction of a second in his own home. The majority of us in this country are only just beginning to hear of the application of electronics in the industrial field, but, as I see it, there is no reason why electronics should not in future years revolutionize industrial life, as it has already revolutionized social life. There are innumerable processes in modern industry—sorting, testing, measuring and processes of that kind, almost automatic tasks—which are both fatiguing and, I should imagine, intensely boring. Up to now most of them have had to be done by human agency, because there has been no alternative; but how much better it would be if a great many of them could be done by machine.

"In this country, as I have said, such ideas are still in their infancy; the United States of America is already ahead of us in exploiting such equipment. Possibly the reason is that American labour costs are so high that even expensive machines of this kind represent a saving; but also I am afraid—at least, I have been told so, and I see no reason to doubt it—that American manufacturers are perhaps at present rather more susceptible of new ideas than are some of our British industrialists. However, whether it is going to come fast or slow, the automatic factory is certainly on the way; and what a vista that opens up of leisure and of relief from exhaustion and strain for the whole of our working people!

"If, therefore, we are tempted to rest on our oars and to consolidate a position which has been reached, before again starting to move forward, I hope we shall not give way to such temptations. The prize is so glittering and so fraught with advantage for the whole human race that I feel we cannot afford to delay.

"Let us, then, regard this jubilee not only as an occasion for looking back with thanks and admiration to Sir Ambrose Fleming for all that we owe him, and with gratitude to those who have followed him, but also as an occasion for straining forward towards that land of promise which his genius has brought within our sight, and almost within our grasp."

In expressing the deep gratitude of everyone present to Lord Salisbury the President said:

"By our rapt attention I measure our interest in what Lord Salisbury has said to us. From his high office he

views the panorama of world events upon the screen of time, and with his sense of history he cannot fail to be impressed by the effect of science and scientific discovery upon our life and times and by the way in which the world has shrunk through the intimacy and speed of our communications. Perhaps one is just being old-fashioned when one occasionally harbours the doubt whether we use these things wisely on every occasion; but if fault there be—and who am I to say that there might be?—I think that it rests at the door of the politicians and not at that of the scientists.

"Lord Salisbury is a statesman and also an educationist. In addition to holding many high offices in previous Governments and being Lord President of the Council in Her Majesty's present Government, he is also Chancellor of the University of Liverpool. I think that that is important, because, with what may be called a bifocal approach to the needs of youth and age, he maintains an unshaken belief in the ability of people to control their own destiny and in the way in which science can help them to do so."

After the President had appreciatively referred to the presence of Lady Fleming at the meeting, he introduced Professor Howe, who gave the first lecture. Next came

Professor Howe delivers his lecture; Sir Edward Appleton is in the right foreground

the lecture by Sir Edward Appleton, Principal and Vice-Chancellor of Edinburgh University, whose name, so familiar to members, is, as the President said, "inscribed in the upper-atmosphere." Summaries of the two addresses appear on pages 158 and 159.

At the end of these lectures, the Chairman of the Radio Section, Mr. C. W. Oatley, expressed to Professor Howe and Sir Edward Appleton the thanks of those present, saying that they were fortunate in having two speakers, each with such an extraordinarily interesting story to tell and such a superb manner of telling it.

Before he adjourned the meeting at 4.30 p.m., the President declared:

"We express our grateful thanks to the Provost and staff of University College, London, who have done so much to assist in the organization of this celebration.

"In connection with the exhibition, our thanks are due to very many people for their kindness in providing equipment and arranging it for us."

The exhibition of valves, which was open to members on November 15th and 17th as well, was staged in the Tea and Common Rooms of the Institution building. It comprised 10 show-cases illustrating in groups the evolution of the thermionic valve from 1904 to the present day.

The subjects for the groups were:

(i) Developments in the triode up to 1918.
(ii) Developments in emission.
(iii) Developments in the diode and triode from 1920.
(iv) Transmitting valves.
(v) Developments for special purposes, such as electrometer valves, long-life valves, and radar modulators.
(vi) Fleming lamps and valves.
(vii) Tetrodes and pentodes.
(viii) Multi-electrode valves.
(ix) Small, midget and sub-miniature valves.
(x) Transit-time devices, such as magnetrons and klystrons.

There were some 250 different types of valve exhibited: included among them were the actual valve with which Fleming succeeded in rectifying high-frequency currents in 1904, the de Forest "audion" (triode), early valves developed by Langmuir and Round, a French R type valve, the original cavity magnetron developed at Birmingham University in 1940, and modern travelling-wave tubes.

When the meeting was resumed at 5.30 p.m., the President introduced Dr. J. Thomson, the Deputy Director of Physical Research at the Admiralty, who gave the third lecture. A summary of this address appears on page 160.

At the close of the lecture Sir Gordon Radley proposed a vote of thanks to Dr. Thomson, ending his speech with the following words:

"I should like to add this, and it is perhaps appropriate that I, as the Chairman of your Papers Committee last year, should do so. To our thanks to Dr. Thomson we should add our thanks to the Chairman of the Radio Section and his Committee, and to their predecessors in office, for their initiative in taking up a suggestion and for the great amount of hard work which they have put into making the arrangements for to-day's Celebration. The day has quickly passed, but it leaves a memory which I am sure will endure for a very long time."

So we came to the end of the day's events. It had been a notable meeting, distinguished for the quality of the speeches and addresses, the fascination of the human story they told, and the breadth of their scientific compass. Members present carried away new thoughts of a remarkable stream of events—thoughts that should serve to help them in comprehending and guiding developments in the next half-century of the thermionic valve.

Journal I.E.E., March 1955

THE GENESIS OF THE THERMIONIC VALVE

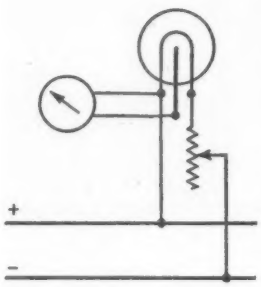
By **Professor G. W. O. HOWE, D.Sc., LL.D.,** *Member*

A summary of the lecture given on the 16th November, 1954, at the Celebration of the Jubilee of the Thermionic Valve.

JOHN AMBROSE FLEMING, who 50 years ago took out a patent for the detection of wireless signals by means of a thermionic valve, was born in 1849 at Lancaster. His father, a clergyman, came of an old Scottish family of Flemish origin. When he was five the family moved to London. At the age of 16 he became a science student at University College, but owing to financial difficulties the classes of his last two years had to be fitted in with work as a clerk in a Stock Exchange office, notwithstanding which he obtained a B.Sc. degree with first-class honours. Except for a break of two years as a research assistant at the Royal College of Science, he spent the next seven years as a science master in schools; he then went to Cambridge and studied under Clerk Maxwell for three years. He left Cambridge in 1881 with a first class in the Natural Science Tripos and a D.Sc. of London University. In 1882 he was appointed "Electrician" to the Edison Electric Light Co., and in 1884 went to America to discuss with Edison the difficulties of the electric lighting industry in Great Britain. Five years before, Edison had patented a carbon-filament lamp, and at the time of Fleming's visit he was exhibiting at Philadelphia something which 20 years later was to lead to the invention that we are celebrating. Edison had fixed a metal plate inside the lamp bulb, close to the filament but not touching it, and connected to the outside apparatus by means of a platinum wire sealed through the wall of the bulb. He connected a galvanometer between the plate and the positive end of the incandescent filament, as shown in the diagram, so that most of the filament was negative with respect to the plate. He found that a current passed through the galvanometer and deflected the pointer; the brighter the filament the greater the current and the deflection. All this had nothing to do with wireless, which was then unborn. Edison was concerned with maintaining automatically the correct voltage in electric power stations and he saw in this device a method of doing this. The lamp filament was supplied from the power-station voltage; if the voltage rose above the normal value, the filament became brighter and the current passing through the galvanometer increased; if the voltage fell below normal, the filament became dull and the current decreased. The movements of the galvanometer pointer were made to operate a device which controlled the voltage of the dynamos.

Fleming became interested in this Edison effect, and on his return he had some similar lamps made and experimented with them. He gave lectures on the subject in London in 1890 and 1896. He found that, on applying a battery, negative electricity could pass from the hot filament to the cold plate, but not in the opposite direction, and he assumed at first that this was due to the emission of carbon particles from the filament, which were known to blacken the bulb, but in 1899 J. J. Thomson showed that it was due to the emission of electrons. As Fleming said, "The space between the filament and the metal plate is a *one-way street* for electricity."

In 1885 he became Professor of Electrical Engineering at University College, London, but his first association with wireless was 14 years later, in 1899, when he was appointed scientific adviser to the Marconi Co. His main activities were in connection with the design and equipment of the station at Poldhu, from which the first signals were transmitted across the Atlantic. It was in October, 1904, 20 years after his visit to Edison, that it suddenly occurred to him that the Edison effect could be used to rectify alternating currents of high frequency, and thus convert them into direct currents which could be easily detected. On November 16th he applied for a patent, which in terms of his agreement, became the property of the Marconi Co. The patent applied only to diodes, or two-electrode valves, and their use for rectifying alternating currents. Unfortunately he made the claims too broad, and the Marconi Co. later issued a disclaimer limiting the patent to the rectification of very high frequencies. A strange thing happened later in the United States, where in 1943, i.e. 21 years after the expiration of the patent, the Supreme Court ruled that these claims for more than he had really invented invalidated the whole patent.



The invention in 1906 of the triode, or three-electrode valve, by de Forest in America led to much bitterness and almost endless litigation. This valve was really based on a different principle; instead of rectifying the received signal current, de Forest used it to vary the voltage of a fine wire grid placed between the hot filament and the cold metal electrode. A battery was used to send a steady current through the valve and through a telephone receiver in series with it, but when a wireless signal was received it affected the grid voltage, and thus varied the current through the valve and telephone receiver.

Although this three-electrode valve had a greater effect on the development of radio reception than had the two-electrode valve, and gradually replaced all the earlier detectors such as coherers, and crystal, electrolytic and magnetic detectors, Fleming must undoubtedly be given the credit of being the first to apply thermionic phenomena to wireless detection.

He was knighted in 1929, and died in 1945.

THERMIONIC DEVICES FROM THE DEVELOPMENT OF THE TRIODE UP TO 1939

By Sir EDWARD APPLETON, G.B.E., K.C.B., M.A., D.Sc., LL.D., F.R.S., *Honorary Member*

A summary of the lecture given on the 16th November, 1954, at the Celebration of the Jubilee of the Thermionic Valve.

THE invention of the three-electrode valve (the "audion"), by Lee de Forest in 1907, enormously increased the applicability of thermionic devices, though some years elapsed before such extended possibilities were recognized and appreciated. It seems clear that the introduction of the grid into the two-electrode Fleming valve was prompted by a desire to increase the sensitivity of the latter as an oscillation detector. Only later were the amplifying and generating properties of the triode disclosed.

For a while, the early development of the audion took place mainly in the United States; though von Lieben, in 1911, gave a demonstration of his own three-electrode valve as an amplifier before a German scientific society in Berlin. The audion of de Forest contained an appreciable quantity of gas, and progress in utilization was slow until Langmuir emphasized the need for really high vacuum conditions and showed how they could be produced and maintained in the sealed-off condition. Armstrong, a young research worker at Columbia University, gave, in 1914–15, an illuminating account of the operating characteristics of the audion, based on experiments designed with great insight, which is generally admitted to have been a major factor in directing attention to the great potentialities of three-electrode tubes. Armstrong's audions were made by himself, acting on advice from Langmuir. Meanwhile Arnold, of the Western Electric Co., had successfully developed the audion as a telephone repeater operating with relatively low anode potentials. In this case the extreme exhaustion of the vacuum tubes advocated by Langmuir was not, however, achieved.

The major British contributions to the early development of the triode were made by Franklin and Round. Franklin discovered the phenomenon of retroaction, or feedback, for high-frequency amplification in 1912, while Round developed a notable pair of really hard valves, the V24 and the Q types, and also discovered, in 1913, that a triode could be used as a generator of high-frequency oscillations. Armstrong, in the United States, and Meissner, in Germany, made the same discovery at about the same time.

The First World War gave a major fillip to valve development, since triodes were required, of stable performance, long life and uniformity, for use in radio-communication. In France, Britain and the United States it was found that such satisfactory tube characteristics could be obtained only with thoroughly evacuated tubes, the pioneer investigations of Langmuir being of major importance in this connection. Important work in hard-valve design for defence needs was carried out, in Britain, by Gossling and Fortescue. By the end of the war the operation of the triode as radio detector, amplifier and generator of oscillations was fully understood. Indeed, broadcasting was started with the triode, though its limitations were by then fully recognized. The influence of the deleterious effect of inter-electrode capacitance in causing uncontrollable, and therefore undesirable, reaction between the input and output circuits of a triode was eliminated by the introduction of a screening grid between control grid and anode, so turning a triode into a tetrode. In the practical achievement of this step, pioneer work was done by Round.

The tetrode as thus developed was, however, soon recognized as having limitations in distortionless amplification, owing to secondary-emission phenomena. Two methods of eliminating the effect of such secondary emission were developed by Holst and Tellegen. In one, a suppressor grid was introduced between anode and screen grid, turning a tetrode into a pentode; in the other, the electrode system was so devised as to encourage space-charge formation and thus a potential minimum between screen grid and anode. Before 1939, pentodes had become extremely popular for both high- and low-frequency amplification. Another type of valve having inherently novel features was the variable-mu valve, used to permit the output of a receiver to be adjusted to any desired level without distortion when receiving strong or weak signals.

During the period up to 1939 the two-electrode valve of Fleming had been employed almost solely as a power rectifier for electric mains sets; but near the end of this period the Fleming valve came back into use as a high-frequency detector and as an essential element in automatic-volume-control circuits. Such applications led to further developments in the more complicated types of valves, e.g. double-diodes, double-diode triodes and double-diode pentodes. Also, before 1939, tubes with multiple control grids had been developed—such as hexodes, heptodes and octodes—though these tubes did not involve any inherently new phenomena. The use of two control grids for the simultaneous dual control of the electron stream was of basic utility in frequency-changing in superheterodyne receivers.

Much use was also made of hard thermionic tubes in electrical measurements, normal valve types being employed, for example, in high-frequency voltmeters. A notable new type of triode was the electrometer valve, the construction of which ensured a remarkably high grid insulation.

At the beginning of the First World War valve filaments

were made of tungsten, but, as time went on, oxide-coated filaments were used for receiving valves. Before 1939 the indirectly heated type of cathode had been introduced for mains sets. But nickel remained the popular material for anodes and for electrode support wires. Nickel, however, was not sufficiently rigid for the winding wires of grids, and so molybdenum or alloys containing molybdenum were employed for this purpose.

By 1939, the use of the hard triode and its descendants, as radio generator, amplifier and detector, had already vastly expanded our most natural mode of communication—by voice and ear. The thermionic valve had already become the primary tool of radar, television and sound recording. But it had also become one of the most important tools of scientific research, replacing mechanical devices wherever a delicate and nimble indicator was required.

DEVELOPMENTS IN THERMIONIC DEVICES SINCE 1939

By **J. THOMSON, M.A., D.Sc., F.Inst.P.,** *Member*

A summary of the lecture given on the 16th November, 1954, at the Celebration of the Jubilee of the Thermionic Valve.

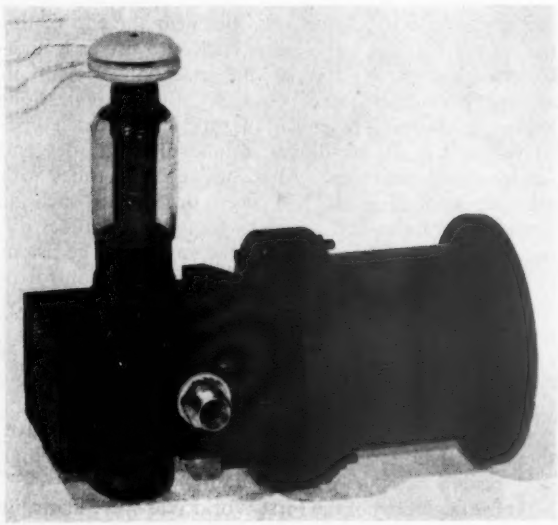
THERE is to-day in this country a large and flourishing electronic industry, whose influence is continually widening. Here an attempt is made first to assess the function of the valve in modern electronic equipment; then to describe the advances which have been made in the microwave region of the spectrum; and finally to discuss the importance of reliability and the success so far achieved in this field.

The active part of any electronic device is essentially a means of transforming one kind of electrical energy to another. The valve is such a device. It may be used to transform direct current to alternating current, or vice versa. It may be used to distort the sum of two waves, as in modulation, or to distort a complex wave so that one of its components may be emphasized, as in demodulation. In every case the valve acts as an amplifier-distorter similar to a dynamo or alternator in that it transforms one kind of energy to another, but unique in that its speed of response is enormously greater than that of any mechanical device.

The speed of response of the valve is obtained because the electron has an extremely small inertia, but the inertia is not by any means negligible where the needs of modern electrical engineering are in question. Up to frequencies of about 300 Mc/s the conventional space-charge-variation principle may be used to construct satisfactory valves, but above 300 Mc/s the electron inertia becomes important and a new method of coupling the electron stream to the electromagnetic circuit must be employed. The most successful alternative to space-charge variation is velocity variation, employed in the so-called velocity-modulation valves. These are klystrons, travelling-wave tubes and magnetrons, although in magnetrons the action owes at least as much to space-charge as to velocity variation.

Valves are now becoming available which allow engineers to employ conventional medium-wave techniques at all frequencies up to 30 000 Mc/s. On the transmitting side, reasonably broad-band high-gain amplifiers can be made, giving c.w. power outputs of the order of a kilowatt. On the receiving side, superheterodyne receivers, tunable over a very wide band and having noise factors of a few decibels, can be designed for all centimetric wavelengths. There are clear indications that low-level modulation of high-power high-gain amplifiers will be achieved: there are grounds for believing that broad-band receiver amplifier valves of very low noise factors can also be made. Valves capable of amplifying at microwavelengths can be employed as wide-band amplifiers for signals of more moderate frequencies, if the lower-frequency signal can be easily applied to the ultra-high-frequency carrier as a modulation. Low-level modulation of microwave amplifiers is thus very desirable. A valve has already been designed to which low-level pulse modulation may be applied.

Fig. 1 shows a typical high-power magnetron for use at a wavelength of 10 cm, and Fig. 2 a klystron amplifier for use at a wavelength of 10 cm. The output is several megawatts in the pulse. It has a gain of 1 000. Fig. 3



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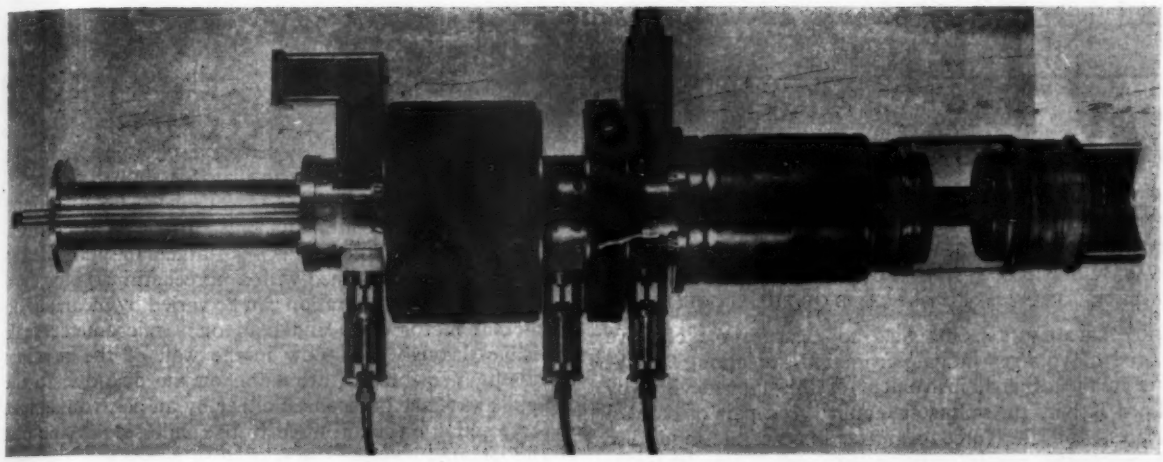

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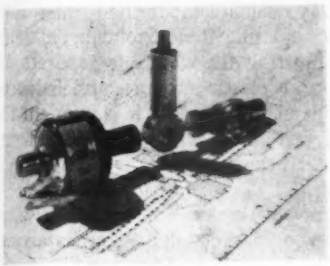

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shows a transmit-receive switch for use in radar at a wavelength of 8 mm. These are examples of modern valves of British development for use at ultra-high frequencies.

An extensive development programme over the years 1946–53 has given us much more reliable miniature and subminiature receiving valves. Attention has been directed towards the inherently weak structures in such valves by large-scale tests under conditions of severe shock and vibration. Structures have been strengthened: better materials have been employed: assembly of parts, processing and pumping have been overhauled. The net result has been to improve the reliability of valves by a very large factor for use in means of transport, factories and workshops.

Other investigations are showing how to construct valves which have lives of the order of 100 000 hours, for use in situations where the equipment must run unattended for many years. Our understanding of the factors affecting the life of the valve is improving rapidly as a result of these investigations.

Research into new materials for use in valve manufacture has already paid dividends and is likely to be even more successful in the future. Many of the materials used at present are much too variable in their properties to allow of adequate quality control. Other materials have not the best properties for the functions which they have to perform. Research must and will bring to light both improved materials and improved methods of making existing materials. Two of the more troublesome components are tungsten wire and mica.

Other valves which have been developed and improved since 1945 include hydrogen thyratrons, capable of working at 100 amp peak current, conventional transmitting triodes and tetrodes, cold-cathode valves (and in particular ring counters), precision cathode-ray tubes and storage tubes. Fig. 4 shows a modern electronic storage tube, using a photo-sensitive mosaic.

In the next half-century the use of electronic methods of control in all departments of human activity is to be expected. The valves for this are available.

4

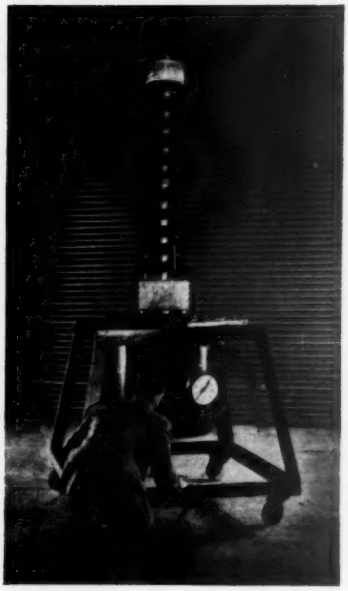
The full texts of the Lectures, together with an appreciation of Sir Ambrose Fleming and Lee de Forest by Capt. C. F. Booth, are contained in a book of some 75 pages to be published by The Institution shortly, at a price (post free) of 9s. to the public and 4s. to members of The Institution.

Attracted-Disc Voltmeter

A DIGEST OF A MEASUREMENTS SECTION PAPER (No. 1675) ENTITLED "AN ATTRACTED-DISC ABSOLUTE VOLTMETER," BY G. W. BOWDLER, M.SC. THE FULL PAPER WAS PUBLISHED SEPARATELY IN JULY, 1954, AND IT WILL BE REPUBLISHED IN PART B OF THE PROCEEDINGS.

THE INSTRUMENT is designed to measure the effective value of voltages ranging from 1 kV to about 500 kV. As in the original instrument of this type devised by Lord Kelvin, the voltage is applied to a pair of parallel plates, and the force of attraction acting on a disc forming the central portion of one of the plates is measured. The voltage can be calculated from the force and the dimensions of the electrode system, so that the instrument does not need to be calibrated against any other standard.

By enclosing the electrodes in a medium of high dielectric strength (nitrogen at a pressure of 15 atmospheres), their dimensions, for a given voltage rating, can be made considerably less than those of an instrument operating at atmospheric pressure, and disturbances due to air currents and deposition of dust on the electrodes are avoided. The enclosed type of instrument, on the other hand, calls for an insulating support for the high-voltage electrode which will withstand both the maximum operating voltage and the internal gas pressure. Up to the present, a porcelain cable sealing-end has been used as the high-voltage insulator, but this has limited voltage measurements to 350 kV (peak); a photograph of the instrument fitted with this insulator is shown. A resin-bonded-paper insulator has recently been obtained, and this should enable measurements to be extended to the design value of 700 kV (peak). All the data published in the paper were obtained with a porcelain insulator.



The attracted-disc voltmeter

The electrode separation can be varied by means of an internal motor drive and read on a micrometer scale visible through a window in the wall of the pressure vessel. The force of attraction on the disc due to the applied voltage is balanced either by an electromagnetic force acting on a coil fitted to the underside of the disc and situated between the poles of a permanent magnet, or by a 100 g weight which can be loaded on to the underside of the disc by a relay mechanism; in the former case balance is obtained by adjusting the current in the coil, and in the latter by adjusting the electrode separation. The disc is mounted on an elastic support, and balance of the opposing forces is achieved when it is brought to its normal position of rest; a detector of displacement of the disc sensitive to less than 1 micron is used during the balancing operation.

The estimated accuracy of measurements made with the instrument increases with the voltage and is about 1% at 1 kV and 0·1% at 30 kV and above.

Stabilized Supplies for High-Resolution Microscopes

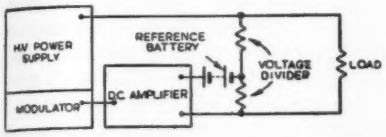
A DIGEST OF TWO MEASUREMENTS SECTION PAPERS (Nos. 1729 AND 1730) ENTITLED "THE USE OF AN ELECTRON VELOCITY ANALYSER TO STABILIZE A 50 KV DIRECT-VOLTAGE SOURCE TO A FEW PARTS IN A MILLION," BY M. E. HAINE, M.SC., F.INST.P., MEMBER, AND M. W. JERVIS, M.SC.TECH., ASSOCIATE MEMBER, AND "A PRECISION DIRECT-CURRENT STABILIZER," BY M. W. JERVIS, M.SC. TECH., ASSOCIATE MEMBER. THE FULL PAPERS WERE PUBLISHED SEPARATELY IN OCTOBER, 1954, AND THEY WILL BE REPUBLISHED IN PART B OF THE PROCEEDINGS.

AN EXPERIMENTAL ATTEMPT to achieve a resolving power of atomic dimensions with the electron microscope required a 50-kV d.c. electron-gun supply and a 100 mA lens supply to be stable to a few parts in a million. Mr. Haine and Mr. Jervis describe in their papers the apparatus used to meet these requirements.

The conventional method of stabilizing direct voltages is illustrated in Fig. 1. This arrangement maintains the voltage across the load at V_R/β, where V_R is the reference voltage and β is the voltage-divider ratio. The effects

of mains-voltage and load-current changes are reduced by a factor $A\beta$, where A is the gain of the system. In practice, the stability of output voltage is usually limited to about 1 part in 10^4 by instability in the voltage divider ratio.

A high stability is more easily obtainable with the

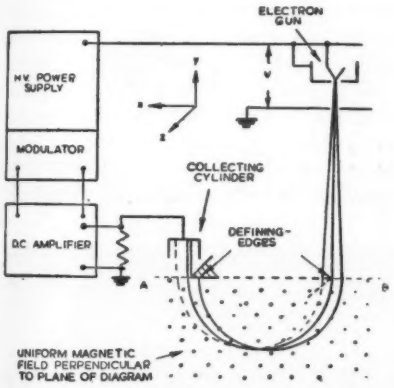


1 *Block diagram of conventional voltage-stabilizing circuit*

new electron-velocity-analyser stabilizer, shown diagrammatically in Fig. 2. Electrons from an electron gun are accelerated through the potential to be stabilized. They are directed into a magnetic field B, where they are deflected in a semicircular path, the diameter x_D of which is given by

$$x_D = \frac{6{\cdot}7\sqrt{V}}{B} \text{ centimetres} \quad . \quad . \quad . \quad (1)$$

Variations in the high voltage alter the diameter of the path, and therefore the number of electrons passing the

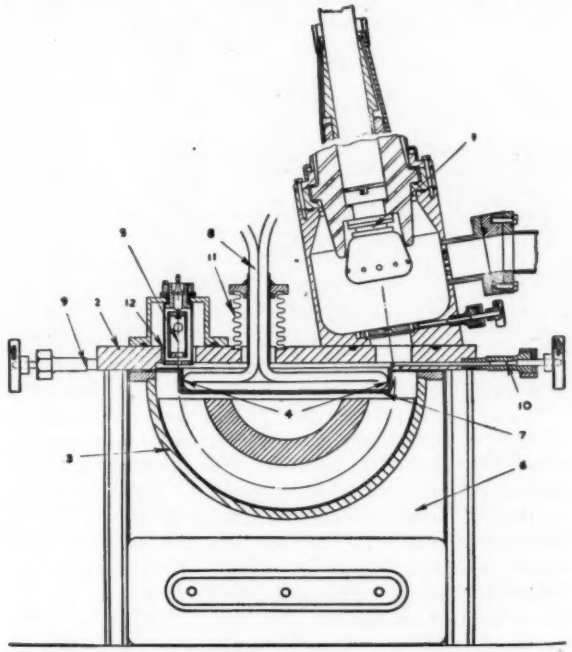


2 *Block diagram of velocity-analyser voltage-stabilizing circuit*

left-hand defining edge. This electron current is collected and passed through a resistor. The voltage developed is then amplified and fed back into the h.v. power supply. The output voltage is then stabilized at a value fixed by the defining-edge separation and the magnetic field strength. The defining edges are fitted on the ends of a rigid temperature-controlled bar, and so their separation can be kept very stable. The magnetic field is obtained either from a temperature-controlled permanent magnet, or from an electromagnet supplied by the current stabilizer described later.

A cross-section of the analyser is shown in Fig. 3.

Besides having a high internal stability, the analyser delivers a large signal to the d.c. amplifier, so that amplifier instability is unimportant; for example, if the amplifier input resistor is 10 megohms, the change in voltage at the amplifier input, for a 1 in 50 000 change



3 *Cross-section of 180° magnetic velocity analyser*
Distance between vertical support rods = 25 cm.

in the 50 kV line, is about 2 volts. This is in marked contrast to the arrangement shown in Fig. 1, where, in a practical case, the corresponding voltage would be 0·005 volt and the amplifier input stability problem quite serious.

For a large reduction of the effects of voltage and load-current variations, a high loop gain $A\beta$ is required. The maximum loop gain which can be used without the onset of oscillation is related to the frequency response of the system. The h.v. supply has a poor h.f. response, and since it forms part of the loop, it limits the maximum usable gain. In the system used the h.v. supply is bypassed with a separate h.f. amplifier having a good response up to 30 kc/s.

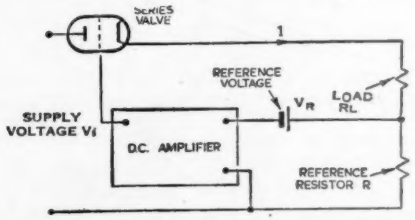
In use, the voltage output of the stabilizer can be relied upon to a few parts in a million over ten-minute periods.

A direct current of 50–150 mA, stable to a few parts in 10^6, is required for energizing the electromagnet supplying the magnetic deflecting field of the voltage stabilizer, and for the magnetic objective lens of the electron microscope.

A conventional degenerative-feedback current stabilizer is used, the arrangement being shown in Fig. 4. This system stabilizes the load current I at a value given by

$$I = V_R/R \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where V_R is the reference voltage and R is the reference resistance. Load-resistance and supply-voltage changes



4 *Degenerative feedback current stabilizer circuit*

have a very small effect if the gain of the d.c. amplifier is sufficiently high.

It can be seen from eqn. (2) that the load current is directly dependent on the reference resistance and the voltage, so that these must be stable to the same degree as that required in the output current. Input instability of the d.c. amplifier can be regarded as changes in the reference voltage, so that the amplifier must have an input instability which is small compared with the reference voltage. This requirement is met by the use of a contact-modulator type of d.c. amplifier. The required reference-resistance stability is obtained from temperature-controlled resistors wound from low-temperature-coefficient wire. A 5·2-volt battery of mercury dry cells is used as the reference voltage. These cells have been found to be very stable and have a low temperature coefficient of e.m.f. As in the voltage stabilizer, a high-frequency feedback channel is provided to by-pass the contact-modulator amplifier, since this has a low gain at high frequencies.

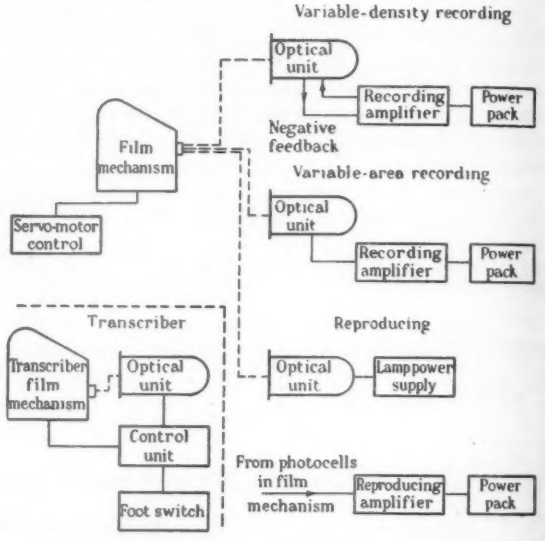
A d.c. loop gain of 40 000 is used and, when checked with a temperature-controlled resistor and Weston cell, the load current was found to be stable to 4 parts in 10^6 over each hour.

Recording and Reproduction of Electrical Signals

DIGEST OF A MEASUREMENTS SECTION PAPER (No. 1696) ENTITLED "EQUIPMENT OF INSTRUMENTAL ACCURACY FOR RECORDING AND REPRODUCTION OF ELECTRICAL SIGNALS, USING CINEMATOGRAPHIC FILM," BY H. McG. ROSS, M.A., ASSOCIATE MEMBER. THE FULL PAPER WAS PUBLISHED SEPARATELY IN AUGUST, 1954, AND IT WILL BE REPUBLISHED IN PART B OF THE PROCEEDINGS.

THE PAPER DESCRIBES transportable equipment for recording electric signals and subsequently reproducing them on play-back. The apparatus is intended to be an adjunct to electrical measuring equipment and therefore has to provide an accuracy comparable with that usually associated with typical electrical instruments. The errors are within $\pm 1\%$ over most of the range, but increase at the maximum amplitude and frequency; the frequency range is 0–1 kc/s. In comparison with the usual techniques of sound reproduction this represents a reduction of errors by about one order of magnitude—a result which has been obtained by careful attention to every detail of the overall recording and reproducing process. A thorough discussion is given of the type and magnitude of the residual errors in the system.

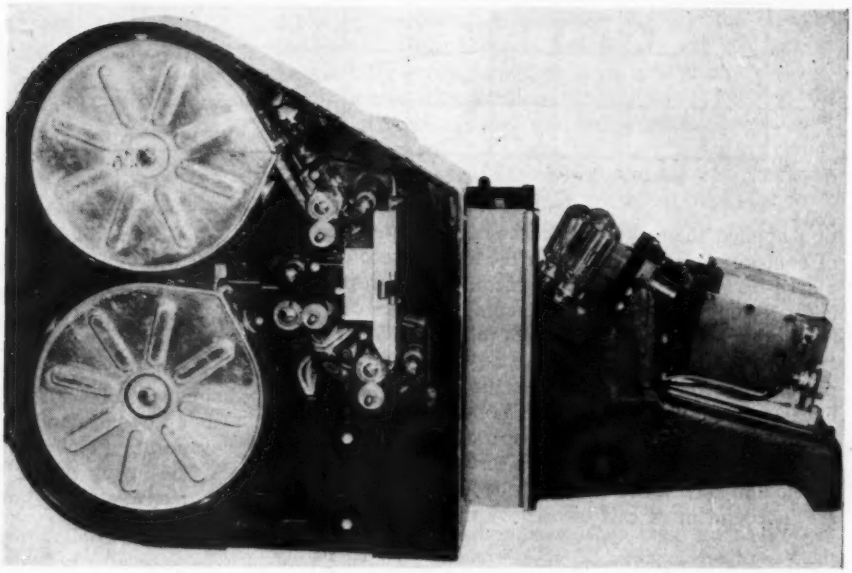
The primary application of the equipment (Fig. 1) is



1 *Block diagram of components of recording and reproducing equipment*

for recording the results of experiments of short duration or of a non-repetitive nature, and for their subsequent reproduction for study or analysis. This permits results to be assimilated by statistical methods, particularly when using an electronic analogue computer, in order to present the information in a condensed and intelligible form. Another use is that records obtained from experiments may be played back repeatedly into experimental apparatus while this is being perfected. Results obtained from experiments taken at different places or times may be correlated together, and complex analysis can be made if required. It is also possible to change the time scale between recording and reproducing. It is thought that, when the possible applications have been more fully explored, the equipment will be found to offer a significant addition to experimental technique.

Cinematographic methods are employed (Fig. 2). A simple film-traversing mechanism is used, driven by a

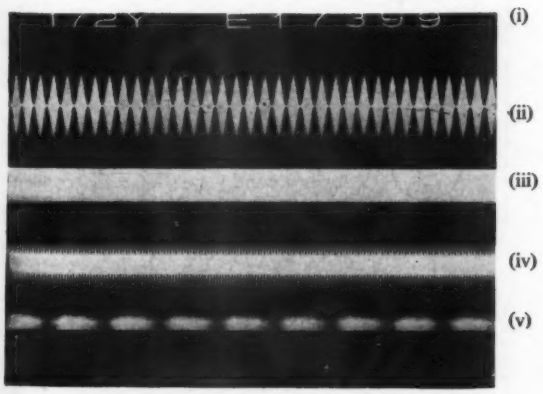


2 *The film mechanism and variable-width recording unit (with covers removed)*

The electronic equipment is housed separately.

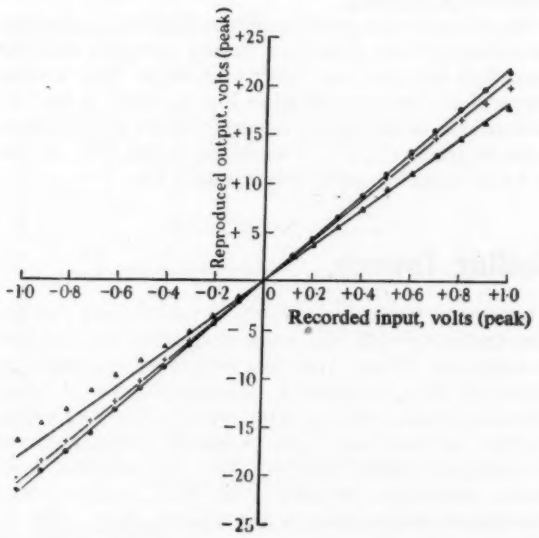
variable-speed motor giving a speed range of at least 500:1. Different optical units are attached to this. One type of recording unit gives variable-density tracks on the film; it uses variable-intensity discharge lamps whose outputs are monitored by photocells to provide negative feedback to the amplifier, to improve the linearity. Another type of optical unit gives variable-width tracks, using modified Duddell oscillographs, the whole system being based on standard cinematographic practices. One purpose of the development was to determine the relative suitability in use of the two techniques, and the variable-width system was found to give significantly greater accuracy, constancy of calibration, simplicity and reliability in operation. These records (Fig. 3) may easily be interpreted visually. For reproduction, an optical unit is attached to the film mechanism, throwing a narrow line of light across the print; the light transmitted through the tracks on the print is measured by photocells. The output voltages from the associated amplifiers are replicas of the voltages which were recorded.

Separate equipment was made for recording informa-



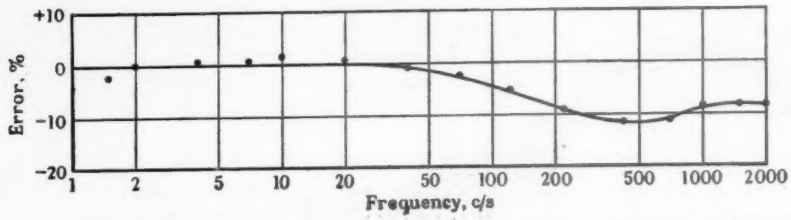
3 *Appearance of a variable-width record of sinusoidal input voltages*

Track (i). Footage number, visible on film before and after processing.
Track (ii). 200c/s, 100% modulation.
Track (iii). Unmodulated track, used for minimizing the errors.
Track (iv). 1 000c/s, 50% modulation.
Track (v). Timing marks, 50c/s; variable transmission.



4 *Direct plots to show the amplitude linearity of the variable-width system*

● Zero-frequency and 10c/s sinusoidal signals.
+ 120c/s sinusoidal signals.
▲ 1 000c/s sinusoidal signals.



5 *Frequency response of the variable-width system, showing the attenuation of the reproduced signal (relative to a recorded signal of constant-amplitude)*

tion applied manually or mechanically by the rotation of control knobs. Prints from the films so recorded are played-back on the other equipment. Its main purpose is for feeding into the analogue computer data obtained from other recording instruments (e.g. ciné-theodolites), tabulated data, random numbers, the equivalent of noise or jitter in radar systems, sinusoidal voltages, non-linear functions, the settings of controls of mechanical equipment or records of the operation of mechanical devices such as the elements of a servo system.

The film carries two tracks of the high accuracy which are independent of each other. A third track of lower

6 *"Noise" level of variable-width system*

Trace derived from a cathode-ray oscillograph connected to the reproducing equipment. The calibration step represents 5% of the full range of recorded signal.

accuracy is available for timing marks, while there is a fourth track which is unmodulated and is used to improve the accuracy.

Fig. 4 shows that good amplitude-linearity is obtained for signals of zero frequency (steady voltages) and also sinusoidal voltages. At higher frequencies there is some attenuation, this being given in Fig. 5. The "noise," or unsteadiness in the output, is seen to have a peak-to-peak value of about 1% of the maximum signal (Fig. 6), but its r.m.s. value is significantly less than this.

Cooling Towers

A DIGEST OF TWO SUPPLY SECTION PAPERS (Nos. 1706 AND 1705) ENTITLED "THE ECONOMIC SELECTION OF COOLING TOWERS FOR GENERATING STATIONS," BY GEOFFREY F. KENNEDY, M.A., M.I.MECH.E., MEMBER, AND P. H. MARGEN, B.SC.(ENG.), ASSOCIATE MEMBER, AND "THE APPLICATION OF FRICTION/HEAT-TRANSFER CORRELATIONS TO COOLING-TOWER DESIGN," BY P. H. MARGEN, B.SC. (ENG.), ASSOCIATE MEMBER. THE FULL PAPERS WERE PUBLISHED SEPARATELY IN SEPTEMBER AND AUGUST, 1954, RESPECTIVELY, AND THEY WILL BE REPUBLISHED IN PART A OF THE PROCEEDINGS.

ELECTRICITY GENERATION and many other industrial processes involve the rejection of large quantities of heat to the surroundings. Where these processes are sited remote from large rivers or estuaries (the most suitable heat receivers), the heat must be rejected to atmosphere using water/air heat exchangers known as cooling towers. In these, the warm water is exposed openly to a current of air caused either by the natural draught set up in a chimney 250–300ft high, or by the mechanical draught set up by fans, and as a result gives up heat to the air by evaporation and convection heat transfer.

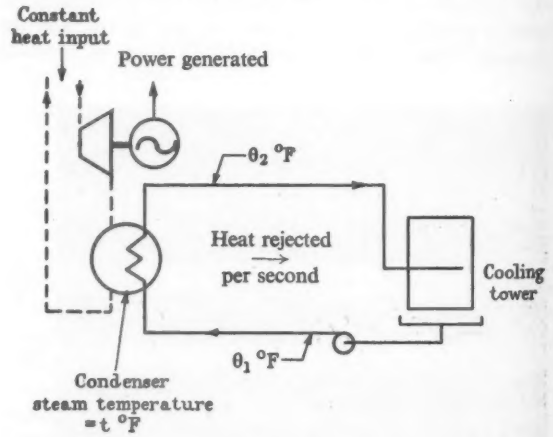
The two papers covered by this digest review respectively:

(*a*) The cooling-tower selection process, in which the designer of a generating station determines the type of tower to be called for and the economic performance specification.

(*b*) The cooling-tower design process, in which the maker determines how the performance specification can be met in the most economic way.

(*a*) *Economic Cooling-Tower Selection*

Fig. 1 shows a typical circulating-water arrangement for a cooling-tower generating station. The circulating



1 *Generating-station cooling circuit*

$(\theta_1 + \theta_2)/2 = \theta_m$

water absorbs heat in the condenser and its temperature rises from θ_1 to θ_2 °F. It then passes through the cooling tower, where its temperature returns to the original value of θ_1 °F. The bigger the tower, the lower is the

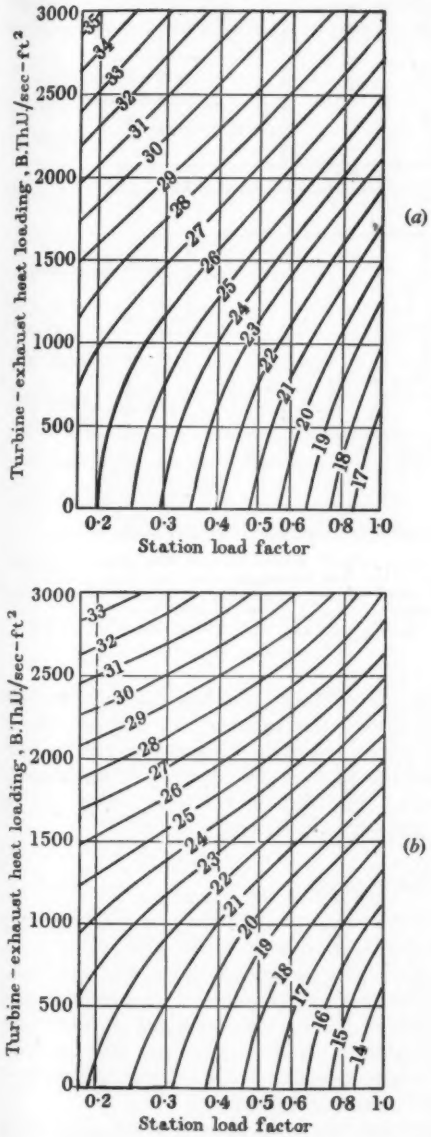
mean circulating-water temperature, $\theta_m = \frac{1}{2}(\theta_1 + \theta_2)$, for a given rate of heat rejection and given atmospheric conditions.

The advantages of a big tower is that it produces a relatively high thermal efficiency of generation; its disadvantage is that it involves a large capital cost. For any given conditions there is a definite value of the mean water temperature which results in the best overall economy.

The main conditions which influence the economic value of the mean temperature, θ_m, are the climate, the annual cooling-tower load factor, and the rate of heat rejection per square foot of net turbine exhaust area (termed the turbine exhaust heat loading, q_e) which determines the turbine performance/vacuum characteristic.

An increase in load factor increases the importance of maintaining a high thermal efficiency and therefore reduces the economic value of the mean water temperature. An increase in the turbine-exhaust heat loading has the opposite effect, since it reduces the gradient of the turbine efficiency/vacuum characteristic. These points are illustrated by Figs. 2(*a*) and 2(*b*), which show the calculated economic values of the mean cooling-tower temperature difference ($\theta_m - t_{wi}$) (i.e. the difference between the mean water temperature and the atmospheric wet-bulb temperature), plotted to co-ordinates of annual load factor and turbine-exhaust heat loading for stations in the British climate. The two diagrams relate respectively to natural- and mechanical-draught towers, and indicate that the former type of tower has higher economic water temperatures than the latter.

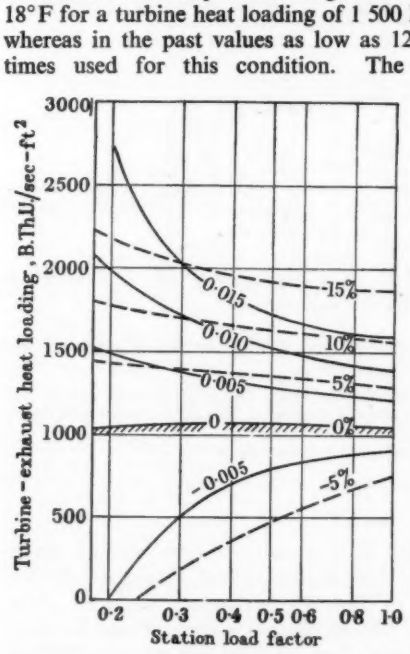
Similar charts are given in the paper for the economic water-temperature range ($\theta_2 - \theta_1$), and the economic mean temperature difference across the condenser. The economic water-temperature range is shown to be about 18°F for a turbine heat loading of 1 500 B.Th.U./sec/ft², whereas in the past values as low as 12°F were sometimes used for this condition. The higher water-



2 *Economic mean temperature difference of cooling towers*

The curves show the temperature difference ($\theta_m - t_{wi}$) to be specified at the reference conditions of atmospheric temperatures: wet bulb = 49°F; dry bulb = 52°F.

(*a*) Natural draught. (*b*) Mechanical draught.



3 *Economic comparison of natural- and mechanical-draught towers for British stations*

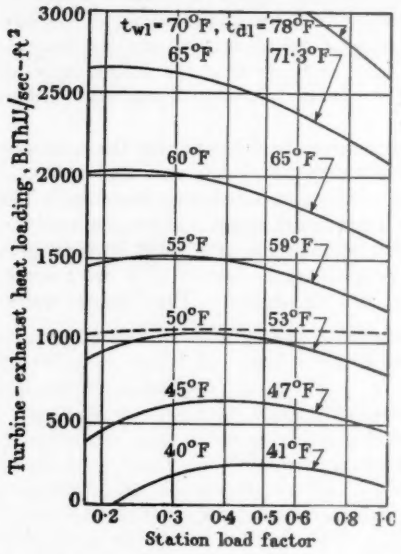
The curves show the total costs of generation with mechanical-draught towers less the total costs of generation with natural draught towers.

——— £ per annum per B.Th.U./sec of full-load heat rejection.
- - - - - Percentage of economic capital charges on natural-draught towers.

temperature ranges and higher mean cooling-tower temperature differences recommended in the paper can, in some instances, save capitalized amounts of £200 000 for a 240 MW station when compared with past practice.

Fig. 3 shows a cost comparison between natural- and mechanical-draught towers for the British climate. The natural-draught towers are economic over the range of conditions above the shaded line, where the chimneys have a relatively high heat loading per unit ground area and therefore produce a large air power per unit capital cost. This range of conditions covers most applications for future British generating stations served by cooling towers alone. Mechanical-draught towers are economic for conditions below the shaded line, which are met mainly with fairly small turbo-generators.

Fig. 4 shows the effect of climate on the economic comparison. The hotter the climate, the less is the air



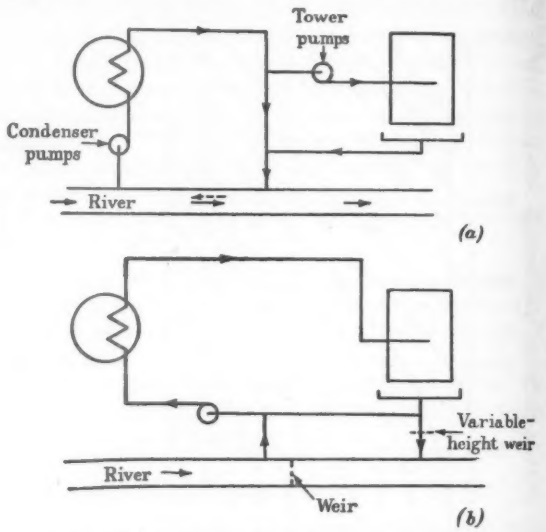
4 *Influence of climate on relative merits of natural- and mechanical-draught towers*

The curves show the conditions under which both towers give the same total costs of generation, natural-draught towers being economic above the curve.

- - - - - British conditions (from Fig. 3).

power developed in a natural-draught cooling tower chimney per unit heat supplied to it. Consequently, hot climates tend to favour mechanical draught. For instance, in the United States, where average air temperatures are more than 10°F higher than in Britain, mechanical-draught towers are used almost exclusively.

Cooling towers have certain disadvantages compared with natural river cooling, i.e. a higher capital cost, higher mean water temperatures and greater circulating-water pumping-power consumption. These disadvantages can often be partially avoided by allowing a small-load river to supplement the cooling-tower installation. For instance, the use of a river which can absorb only 16% of the full-load heat rejection of a 240 MW station during dry periods and 61% during average flow conditions can reduce the capitalized cost of the station by about £550 000. In such combined schemes the towers would often be needed only to limit the downstream river temperatures to acceptable values during periods of low river discharge, using the circuit



5 *Cooling circuits for combined river and tower scheme*

(*a*) Circuit with "shunt" across towers; flow direction reverses during very low river discharges.
(*b*) Simple series circuit; modified arrangements without weirs are possible.

shown on Fig. 5(*a*). Since these low discharge periods occur mainly during the summer, the cooling towers would work under relatively high mean atmospheric conditions and this favours the adoption of mechanical-draught towers. Fig. 5(*b*) is a circuit which can be adopted for relatively small rivers.

(*b*) *Cooling-Tower Design*

The task of the cooling-tower designer is to meet the performance specification with the most economic combination of the main design variables, i.e. the tower ground area, the chimney height or fan power, the heat transfer surface of the packing, and the packing heat transfer and friction characteristics per unit surface. The second paper covered by the digest describes a method of performing this task.

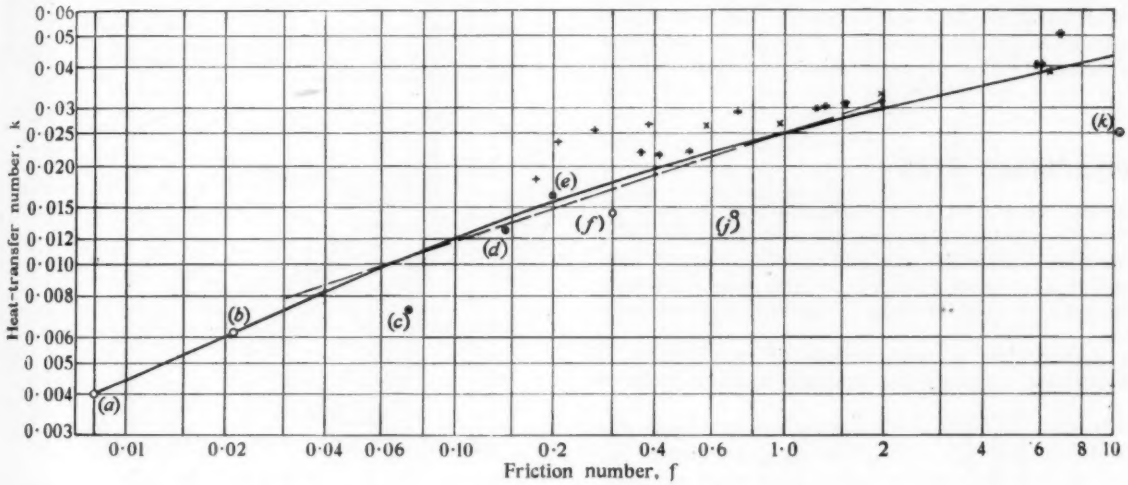
The first problem examined is the method of selecting the friction and heat-transfer properties per unit surface. Theoretical considerations suggest that friction and heat transfer properties of cooling tower packings are correlated, i.e. an improvement in the heat-transfer properties

can be obtained at the expense of an increase in friction. For any given shell design and packing surface, a definite friction factor will then produce the best cooling-tower performance.

The precise nature of the friction/heat-transfer relation depends on the method of changing the shape of the packing, e.g. a progressive change in the alignment of corrugated sheets to produce progressively narrower constrictions in the air-flow path. The limited experimental evidence now available and plotted in Fig. 6, however, suggests that differences between various methods are not pronounced, i.e. that the results for all film-type packings free from the more obvious design faults are reasonably well represented by a general friction/heat-transfer correlation which is represented by the broken line in Fig. 6. For this correlation the design chart, Fig. 7, is prepared from which the optimum friction factor, the economic packing surface per unit horizontal area of the tower area and the corresponding cooling-tower performance coefficient can be read off for any values of two design constants, namely:

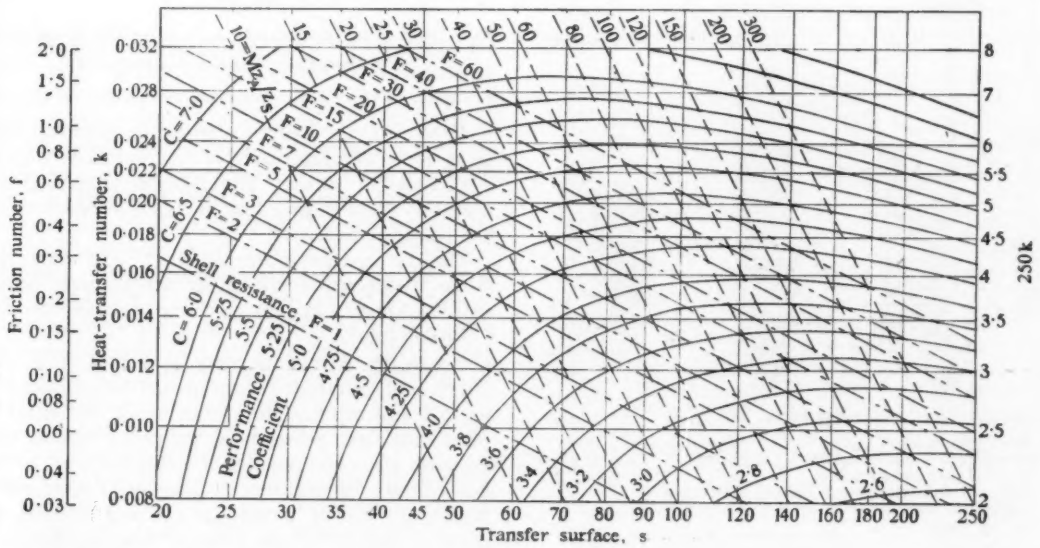
The air-flow resistance, F, of the tower shell.

The comparative cost of extending tower ground area and packing surface, z_A/z_S.



6 *Friction/heat-transfer correlation*

——— Law suggested by data. ---- Linear approximation over range of interest.
Points (*a*)–(*j*) refer to film-type packings. Crosses refer to data on air flow perpendicular to 10 rows of tubes.



7 *Chart for economic tower design*

The optimum friction factor can vary over the range 0·1–0·6, being lowest for small mechanical-draught towers situated on expensive ground and highest for large natural-draught towers.

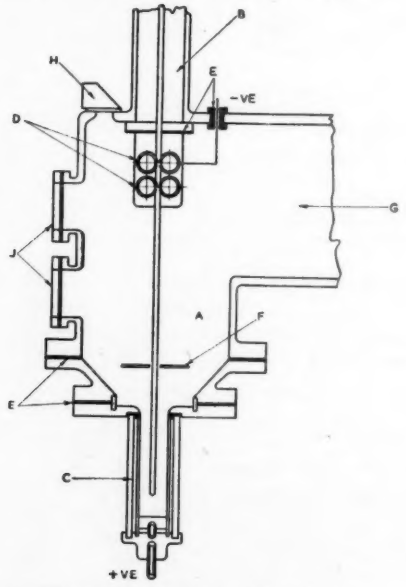
For those film-type packings which do not quite satisfy the general correlation, the design chart may be used in conjunction with two correction factors. For larger departures from the general correlation, such as those to be expected from splash-bar packings, individual design charts can be constructed by the methods described.

Once the packing design per unit horizontal area has been settled, the economic chimney height or fan power per unit horizontal area can be found. The final step in the design is the determination of the horizontal tower area needed to meet the performance specification.

Molybdenum Arcs

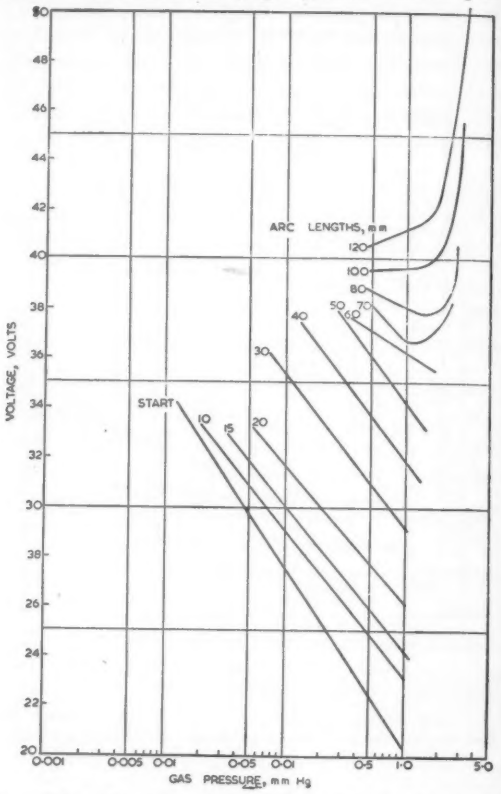
A DIGEST OF A UTILIZATION SECTION PAPER (No. 1768) ENTITLED "CHARACTERISTICS OF THE MOLYBDENUM-DEPOSITING ARC AND THE METAL-ARC MELTING PROCESS," BY A. R. MOSS. THE FULL PAPER WAS PUBLISHED IN FEBRUARY, 1955, IN PART A OF THE PROCEEDINGS.

THE PRODUCTION of solid masses of metals such as molybdenum, tantalum and tungsten in a high state of purity is not possible at present by a conventional melting and casting process, the fundamental difficulty being the lack of a suitable refractory material. The difficulty can be overcome by using the heat of an electric arc and a water-cooled copper mould. This process, using a consumable electrode (Fig. 1), also has its problems,



1 *Schematic of the arc-melting plant*

A. Melting chamber.
B. Extension tube for electrode.
C. Water-cooled copper mould.
D. Electrode drive mechanism and conductor rolls.
E. Insulators.
F. Spatter shield.
G. Vacuum line.
H. Periscope.
J. Windows.

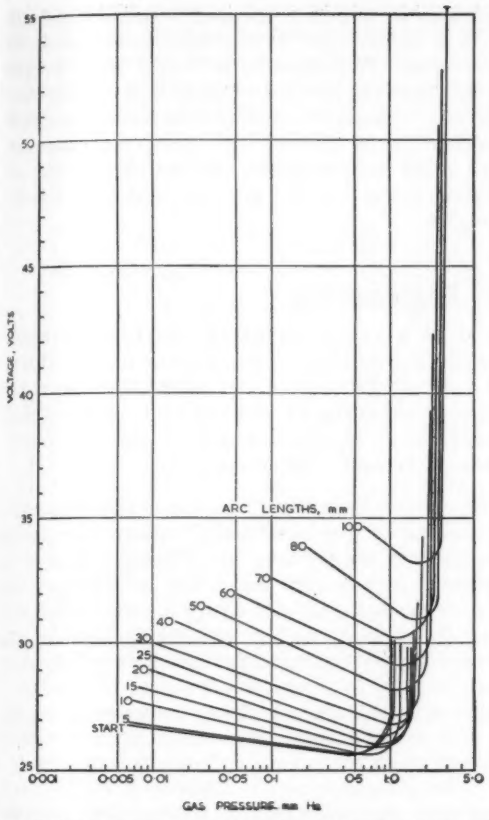


2A *Effect of pressure on total voltage for arcs of various lengths*
D.C. arc with consumable electrode positive.

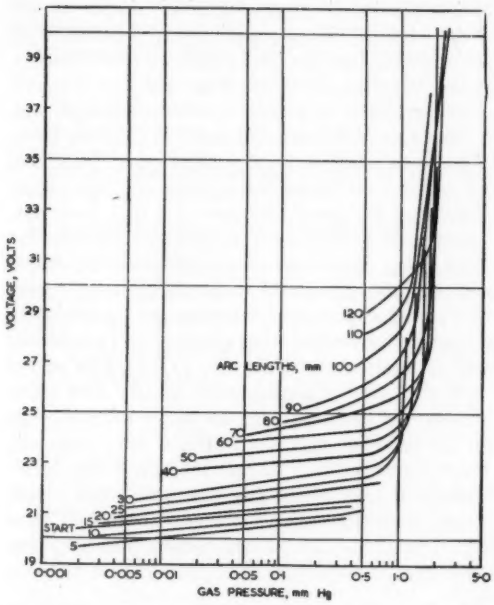
however, and the paper discusses the electrical ones and gives some characteristics of high-intensity arcs (up to 2 000amp) *in vacuo*. The theories suggested may be useful to those engaged on rectifier, circuit-breaker and arc-welding researches.

The d.c. arc has been found to have a trumpet-like shape, the current density at its cathode being determined as 120kA/cm² and that at the anode between 500 and 1 000amp/cm².

Practically all routine melting is now done with the consumable electrode (1 cm diameter) at negative polarity, using 1 300amp and an arc length of $\frac{3}{4}$in at the lowest practicable gas pressure (0·1 micron). With the consumable electrode positive the cathode spot is unstable and causes damage by wandering. Although quite stable, the use of 1 200amp a.c. arcs resulted in poor ingot quality; it is now known, however, that a higher current would have been successful.



2B *Effect of pressure on total voltage for arcs of various lengths*
D.C. arc with consumable electrode negative.

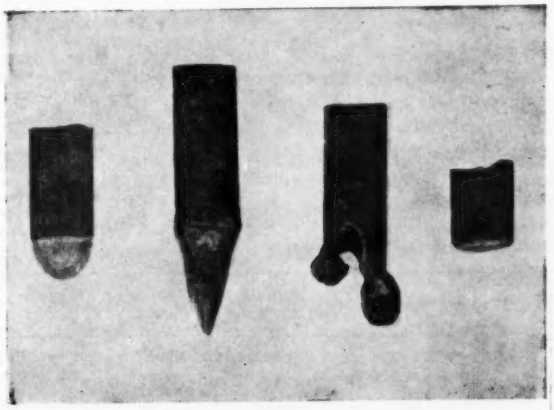


2C *Effect of pressure on total voltage for arcs of various lengths*
A.C. arc.

In a prototype melting plant much trouble was experienced with an unintentional electrical discharge between the consumable electrode and various parts of the plant, resulting in serious damage to those parts at negative potential. The discharge was caused by bridging of the gap (up to 9 in) between parts at opposite potentials by spatter projected out from the arc area. This spatter, having a temperature of up to 5 000°C, would, on passing through high vacuum, leave a trail of molybdenum vapour which would become positively charged as a result of thermionic emission and which could drift electrostatically to parts at negative potential. The troubles were eliminated by insulating the various sections, by using spatter guards and by avoiding the use of materials with low work functions (e.g. silver solders containing cadmium) and those having high vapour pressures when heated (e.g. fibre).

As the behaviour of the voltage on arc lengthening was quite different from that encountered with arcs in air at atmospheric pressure, and as consideration was to be given to the design of an automatic arc-length controller, experiments were conducted to study the variation of voltage with arc length and gas pressure. The principal results are given in Figs. 2A, 2B and 2C. There is some similarity to the characteristic curves of sparks.

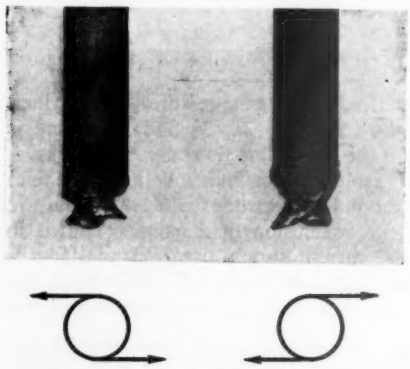
The shape of molybdenum burn-offs, i.e. the end portion of a consumable electrode with which the arc is in contact at the conclusion of a melt, is related to the polarity of the current supply used. Typical burn-offs are shown in Fig. 3. A theory to explain these has been developed: in view of the current densities at the



3 *Typical molybdenum burn-offs produced at 1 kA*
(*a*) Consumable electrode positive.
(*b*) Conical type, consumable electrode negative.
(*c*) Two-drip-point type, consumable electrode negative.
(*d*) A.C. arc.

anode and cathode, the hemispherical shape of the positive burn-off could be expected, for it is bathed over the whole area of its tip in a heat source of low intensity. Similarly the flat a.c. burn-off, Fig. 3(*d*), is not surprising, in view of the alternations of two different heat sources. The reasons for the two types of negative burn-off, i.e. the conical and the 2-drip-point types [Figs. 3(*b*) and 3(*c*)], cannot be explained simply in this digest. Briefly, however, the configurations are due to a systematic movement of the cathode spot causing selective melting, this being dependent on conditions at the burn-off such as: (*a*) changes in the work function following purification of the impure molybdenum due to heating in high vacuum; (*b*) the temperature gradient; (*c*) systematic detachment of molten globules; and (*d*) rotation of the arc around the rod. Combination of the first three factors causes the cathode spot to move vertically up and down the burn-off, and when the arc simultaneously rotates the resolved path is similar to that of saw teeth. At low rotational velocities 2-drip-point burn-offs result, whereas high velocities create the conical types. It was interesting to observe that the arc could rotate in either a clockwise or anticlockwise direction, as can be seen from Fig. 4.

The rate at which the molybdenum rod is melted



4 *The direction of rotation of an arc can be clockwise or anti-clockwise as indicated by the burn-offs shown*

increases with current, and is not significantly influenced by gas pressure.

The Table shows that d.c. supply with the consumable electrode positive produces the largest globules and the lowest burn-off rate and its converse the intermediate-size globules and the highest burn-off rate, while the a.c. supply produces the smallest globules and intermediate burn-off rate. To explain these facts, a theory, based on a consideration of thermal efficiency, the size and intensity of the heating source, and the effective size of the burn-off at the time and position of globule detachment, is given.

Burn-off data for 950amp arcs

Supply	Burn-off rate	Globule diameter	Globule weight
	g/sec	mm	g
D.C., consumable electrode positive	4·2	5·7	0·6–1·8
D.C., consumable electrode negative	5·8	3–4	0·15–0·35
A.C.	4·9	Up to 2½	Up to 0·08

Basic Engineering

A DIGEST OF A STUDENTS' PAPER ENTITLED "A BASIC APPROACH TO ENGINEERING PROBLEMS," BY R. A. HORE, B.SC., B.A., WH.SC., GRADUATE. THE PAPER WAS AWARDED A STUDENTS' PREMIUM BY THE COUNCIL, AND A LONG ABSTRACT OF IT WAS PUBLISHED IN THE STUDENTS' QUARTERLY JOURNAL, SEPTEMBER, 1954.

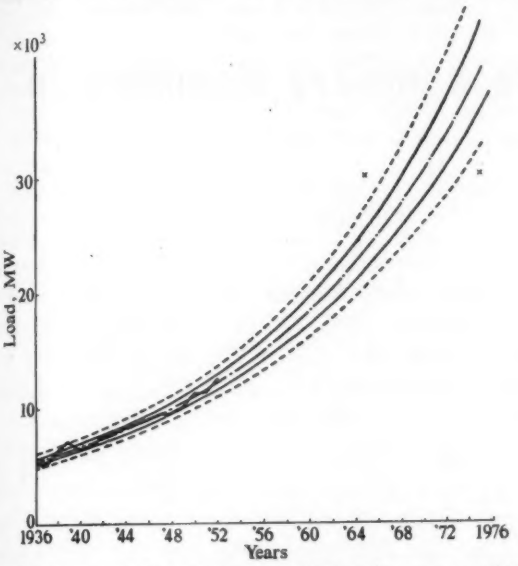
THE WELL-KNOWN DEFINITION "the application of science to the benefit of the community" asserts the social responsibilities of the engineer, which all too often receive less attention than is their due. The definition of the engineer as "a man who can do for a penny what any fool can do for twopence" stresses the financial aspect, which occasionally receives undue reverence. Following Ruskin's warning to those "who consider price alone," an important distinction is drawn between price and value, and, as an example, the choice between hydro-electric and steam generation of electricity is considered; whilst steam generation may be cheaper, in the long run hydro-electric generation may yet be the more valuable by conserving expendable resources. Responsibility to the community implies the truth that the best engineer is he who can achieve the required result with the least expenditure of wealth, but "wealth" and "money" are not invariably synonymous.

The crucial test of engineering, however, is whether it achieves the required result. In other words, the job must work. If a job is an eyesore and a financial and social liability, and yet it works, it is engineering, albeit bad engineering; if it does not work it is not engineering. And whether it works or not is purely a technical matter. Because of the prime importance of the technical aspect, this is discussed in more detail.

It is shown that the solution of practical technical engineering problems can only be achieved by induction. In some cases solutions may be obtained deductively from given "laws of Nature," but these are themselves obtained by induction; whilst the majority of problems can only be solved by experience, as our elders sagely and frequently remind us. This being so, all solutions are estimates (or guesses), more or less accurate according to the degree of certainty with which we infer the law or rule from which we deduce them. The basic approach suggested in the paper is therefore to infer (from experience) a law and the probability of the correctness of the conclusions deduced from it. In this way the maximum use is made of the information (i.e.

the experience) available. Any novelty in this approach lies in its being made explicitly in contradistinction to the more common practice of making it intuitively.

As a practical example of this approach, the problem of load prediction is tackled. The Figure shows the load



The load curve of this country over the last few years, and the predicted loads

curve of this country over the last few years and the predicted loads. An exact prediction is impossible; instead are shown the most likely loads (chain dotted) and the limits between which the actual loads may be expected to lie with various probabilities (the probability that the load lies between the two full lines is 70%; and between the two dotted lines, 95%. The limits are fiducial, not confidence, limits). For comparison with other methods of prediction the B.E.A. estimates of the date at which the national demand of 30 000 MW will be reached are marked with two crosses; the chance of either being correct is less than 1 in 40; but the mean of the two lies near the most likely load (the predictions shown in the Figure are on the low side, because the data are not the true loads, as a result of load shedding over the last few years). An incidental, but not insignificant, advantage of the method is that one engineer can obtain the same answer as another, this being the best guess anyone can make on the basis of past load figures. Whilst this basis is considered satisfactory in this case, it is not invariably adequate.

The versatility of the approach is shown by a further example—the question of protecting a transformer against lightning, where the purely technical answer (i.e. the best protection possible) may be quite wrong. A Table is drawn up showing the probable cost of failure for different schemes, the transformer being *valued* at £60 000 (the treatment is, of course, very much simplified, and is used purely to illustrate the principles of assessment).

We assume the following data:

(*a*) The probability that the unprotected transformer is damaged by lightning during its life is 0·06.
(*b*) The probability is reduced to 33⅓% of (*a*) by the use of earth wires.
(*c*) The probability is reduced to 1% of (*a*) by the use of earth wires and lightning arresters.

The costs of the various schemes are then:

(*a*) *No precautions.*

Cost of failures = 0·06 × £60 000 ..	£3 600

(*b*) *Earth wire.*

Cost of earth wire	£1 000
Cost of failures	£1 200
Total cost	£2 200

(*c*) *Lightning arrester and earth wire.*

Cost of earth wire	£1 000
Cost of arrester	£2 000
Cost of failure	£36
Total cost	£3 036

In this case it is bad engineering practice to provide arresters; and it is good practice to provide earth wires. But if the chance of lightning causing damage were five times as great, the figures would be as follows:

(*a*) £18 000. (*b*) £7 000. (*c*) £3 180.

It would then be advisable to fit arresters.

These examples show how systematic estimations based on experience can give assistance in making engineering decisions which otherwise tend to be made only by intuitive guesswork.

The methodology discussed is generally that expounded by H. Jefferys and is applicable to the technical and financial problems of engineering as well as to science. (This does not imply that the application is always easy, but it does imply that it is worth while.) It is therefore concluded that engineering may informatively be defined as "a system of intelligent guesswork," and that, as no knowledge is certain, its uncertainty should be acknowledged and its probable error assessed. In this way, many problems to which no classical scientific laws are applicable may yet be solved scientifically.

The approach to the very important social aspect of engineering is more difficult, for these problems involve moral issues where there are no experimental data on which inference may logically be based. The author considers that the solution to moral questions can only be based on religious conviction, and suggests that it is not without significance that the vast majority of great engineers have been and are men of firm faith in God. The engineer may not disclaim moral responsibility for the use to which his works are put; and as civilization and barbarism depend on, and are potentially increased by, engineering ability, religion is as relevant to engineering as to other activities.

Photograph by Baron

Election of

H.R.H. THE DUKE OF EDINBURGH

To Honorary Membership

* * *

At the Ordinary Meeting of The Institution on the 3rd February, 1955, the President announced that the Council had elected **His Royal Highness the Duke of Edinburgh, K.G., P.C., K.T., G.B.E., F.R.S.,** to Honorary Membership of The Institution.

His Royal Highness has graciously signified his acceptance of this election, which the Council have made with particular pleasure in view of the lively interest that His Royal Highness has long shown in science and engineering and their applications.

Election of an Honorary Member

AT the Ordinary Meeting of The Institution on the 6th January, 1955, the President announced that the Council had elected **Mr. James Robert Beard, C.B.E., M.Sc., Past-President,** to Honorary Membership of The Institution, for his distinguished services to the profession, more especially in the field of electricity transmission and distribution and in his valuable work for The Institution.

It is well known that Mr. Beard was closely associated with the design and construction of the national Grid system; his name is also associated with numerous other power supply and traction schemes at home and abroad.

Educated at Manchester Grammar School and Manchester University, he spent his post-graduate years with the Newcastle upon Tyne Electric Supply Co. and the Cleveland and Durham Electric Power Co. He joined his present firm, Messrs. Merz and McLellan, as assistant to Mr. P. V. Hunter, succeeding him later as Chief Electrical Engineer; he is now Senior Partner of the firm.

Mr. Beard has performed outstanding services for The Institution over a long period of years. He was elected Chairman of the North-Eastern Centre in 1920, and in 1927 and again in 1934 he was elected a member of Council. He first took office as Vice-President of The Institution in 1937, and served as President in 1940–41. He has always shown particular interest in the affairs of the Local Centres and the Oversea Committees and Branches, and has served as Chairman of the Local Centres and the Oversea Activities Committees of the Council. He has written many Institution papers and has twice been awarded the Institution Premium.

Mr. Beard is a Member of The Institution of Civil Engineers and a Fellow of the American Institute of Electrical Engineers. He was Chairman of the Electrical Installations Study Committee set up by The Institution for the Ministry of Works and was associated from its inception with the Council for Codes of Practice. He was President of the Association of Supervising Electrical Engineers from 1938 to 1940, and in 1945 he was elected Chairman of the Association of Consulting Engineers. Last year he was President of the British Electrical Power Convention. He has served on the Panel of Technical Advisers to the North of Scotland Hydro-Electric Board since its formation in 1943.

Award of the Faraday Medal

AT the Ordinary Meeting of The Institution on the 6th January, 1955, the President announced that the Council had made the thirty-third award of the Faraday Medal to **Sir John Cockcroft, K.C.B., C.B.E., M.A., M.Sc.Tech., Ph.D., F.R.S., Member,** for the conspicuous services he has rendered to the advancement of electrical science, for his distinguished work in the field of nuclear physics and the development of power from nuclear sources.

Sir John Cockcroft was educated at Manchester University and received his practical training as a college apprentice with the Metropolitan-Vickers Electrical Co. After serving on the Company's research staff under Sir Arthur P. M. Fleming, he became Consulting Physicist to the Company in 1927.

In 1930 he was appointed University Demonstrator and Lecturer in Physics at the Cavendish Laboratory, Cambridge. Here, under Lord Rutherford, he developed apparatus for producing high-velocity positive ions, with which, in 1932, he and Dr. E. T. S. Walton were the first to disintegrate the nucleus of an element by the use of artificially accelerated protons. Throughout his period at the Cavendish he was closely associated with all the notable achievements of the Laboratory, and in 1939 he succeeded Sir Edward Appleton as Jacksonian Professor of Natural Philosophy. In the Second World War he was urgently in demand as adviser to many Government Departments. He held the post of Director of the Air Defence Research and Development Establishment at Christchurch and Malvern, and subsequently that of Director of the Montreal Laboratory of the National Research Council of Canada. In 1946 he was appointed Director of the Atomic Energy Research Establishment, Harwell, and he has since been responsible for a period of most intensive development in the field of nuclear energy and its applications.

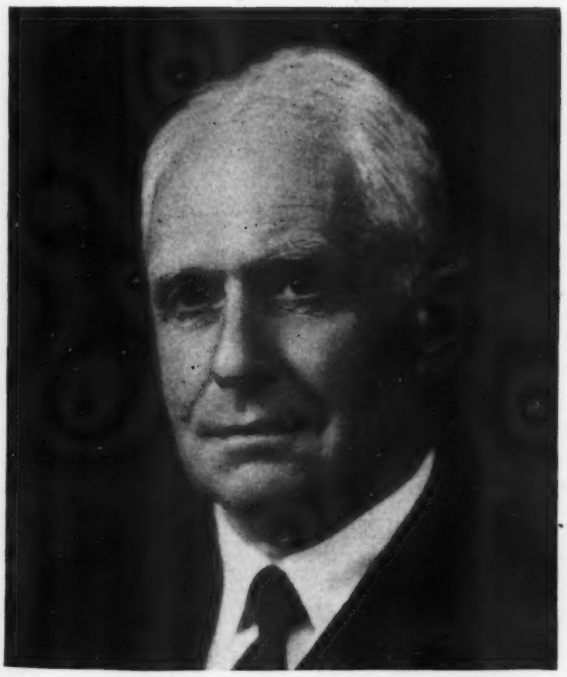
Among other awards Sir John Cockcroft has received the Royal and the Hughes Medals of the Royal Society, the Hopkins Prize of the Cambridge Philosophical Society, the Ewing Medal of The Institution of Civil Engineers, the United States Medal of Freedom, and the Nobel Prize for Physics.

He has written numerous papers on nuclear physics in the *Proceedings of the Royal Society* and on electrical technology in the *Proceedings of The Institution*. He delivered the Kelvin Lecture in 1936 on "The Transmutation of Matter by High-Energy Particles and Radiations," and again in 1951 when his subject was "Modern Conceptions of the Structure of Matter." He is, in fact, one of the very few distinguished scientists who have twice been Kelvin Lecturer.

Sir John Cockcroft was elected an Associate Member in 1927 and a Member in 1941. He served on the Council of The Institution from 1942 to 1945.

J. R. Beard

Photograph by Elliott and Fry



Sir John Cockcroft

Photograph by Fayer

HOME EVENTS

LONDON

ORDINARY MEETINGS

The fourth Ordinary Meeting of the Session, on the 6th January, 1955, took the form of a Joint Meeting with The Institution of Civil Engineers, at which the President, Mr. J. Eccles, vacated the chair in favour of Mr. D. M. Watson, President of the sister Institution. A Supply Section paper entitled *Problems of Hydro-Electric Design in Mixed Thermal-Hydro-Electric Systems* was read by Mr. T. G. N. Haldane and Mr. P. L. Blackstone.

At the Ordinary Meeting on February 3rd, Mr. D. J. Bolton presented another Supply Section paper entitled *A Criterion of Distribution Cost*. This is a paper that is, perhaps, unusually controversial, and it gave rise to a lively discussion, which had to be curtailed at a comparatively late hour by the Chairman, Mr. T. E. Goldup, who was deputizing for the President.

Articles on these two papers will appear in future issues.

MEASUREMENTS SECTION

Precision Instruments

There were rather a large number of empty seats at the meeting on the 14th December, 1954, when three papers were read and jointly discussed. Digests of these papers appear on page 162. The first, *An Attracted Disc Absolute Voltmeter*, was presented by Mr. G. W. Bowdler with the aid of three lantern slides. These included a pictorial view of the complete instrument, which is reproduced in the digest of the paper.

In his introduction to the paper Mr. Bowdler said that, although probably half a dozen papers on the subject had been published in Germany during the past 30 years, none, so far as he had been able to trace, had been submitted to The Institution. This was remarkable inasmuch as neither the principle of an attracted disc nor its application to high-voltage measurement was novel. Indeed, it was virtually the same principle that Lord Kelvin described about 100 years ago, except that its attracted disc operated in compressed gas. Apart from its value to the National Physical Laboratory as an absolute voltmeter for use as an alternative to their existing equipment, it had the advantage that it enabled voltage measurements to be made direct, i.e. without a voltage divider.

It was inherent in the principle that with increased distance and stress between the electrodes the estimated standard error decreased. Thus, the instrument when filled with either nitrogen at 150lb/in^2, or a mixture of nitrogen and Arcton 6 at 50lb/in^2, was capable of an accuracy of within 0·01% in measurement at 30kV and above and not more than 0·1% at voltages between 30kV and 300 volts. Simultaneous measurements with his instrument and a conventional low-voltage instrument used with a divider confirmed his estimates of the errors.

The remainder of the author's time was devoted to a detailed description of the instrument, with its ingenious and intricate mechanism for adjusting the parallelism of the electrodes and for lining up the central disc electrode with its surrounding guard plate. To obtain the accuracy mentioned, these must be coplanar within about one micron, although a somewhat higher degree of unevenness in the actual surfaces and peripheries of these and of the opposing electrode was permissible. To determine the degree of "coplanarity" (to use the author's word) a straight-edge was used. He had with him for demonstration a set of gauges on a surface plate with gaps of 0·001, 0·0001, and 0·00003in, wherewith to convince the incredulous that gaps of those dimensions were easily discernible against a light.

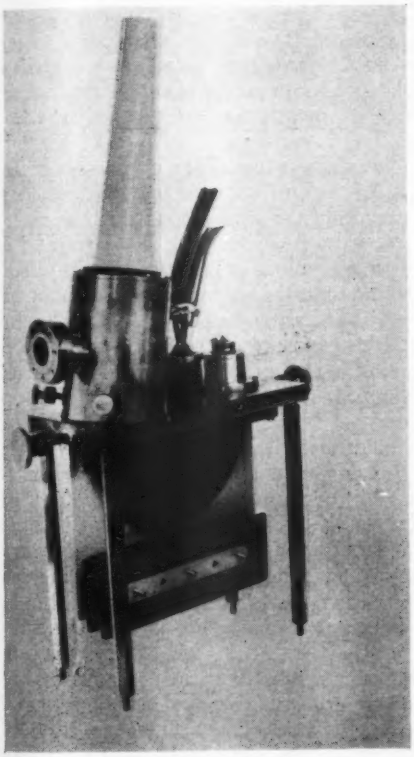
The second paper, *The Use of an Electron Velocity Analyser to Stabilize a 50kV Direct-Voltage Source to a few parts in a Million*, by Mr. M. E. Haine and Mr. M. W. Jervis, was presented by Mr. Haine, with the aid of six lantern slides, one of which, showing a general view of the analyser, is reproduced in Fig. 1. He said that the achievement of a resolving power of atomic dimensions in an electron microscope required a 50kV d.c. supply, stable to 3, preferably to 2, parts in 10^6 without drift for time intervals up to 10min or more. The electron velocity analyser described in the paper was the result of one attempt to meet this requirement.

This method of voltage stabilization was new, although the degenerative feedback circuit incorporated in it was not. Degenerative feedback stabilizers in common use required a voltage divider, and mainly on that account were not capable of a stability better than about 1 part in 10^4. In the electron velocity analyser the voltage divider was replaced by a device based on an electron-optical method, which had the advantages that it gave an input signal to the feedback amplifier at least 1 000 times greater than the fraction of a millivolt obtainable from a resistance voltage-divider; and it did not require a reference battery.

The principle used was to accelerate electrons from an electron gun through the voltage to be stabilized. This is described in more detail in the digest on page 163. This analyser is subject to electron-optical aberrations avoided in other types, but has been found to be the most convenient for its intended purpose, and it could if necessary be improved to give a stability of 1 part in 10^6 and sustain it for several hours.

The third paper, *A Precision D.C. Stabilizer*, was summarized by its author, Mr. M. V. Jervis, and illustrated with five lantern slides. Mr. Jervis said that the electron

velocity analyser and the object lens of an electron microscope both required a stable magnetic field, and several techniques were available for stabilizing it. The nuclear-resonance probe was one example. This and other techniques, however, were not suited to the low field strength of the analyser or to the restricted and non-uniform field of the lens. The required stability for these could most easily be achieved by stabilizing the field current to 3 or 4 parts in 10^6, and for this purpose the degenerative feedback stabilizer was the most satisfactory. In this type the current to be stabilized was passed through a manganese wire resistor wound on brass in a sealed container immersed in a water bath



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at a temperature controlled to 0·05°C. The p.d. thus produced was opposed by a reference voltage V_R obtained from mercury dry cells, which have a temperature coefficient of e.m.f. of less than 20 parts in 10^6 per deg. C (less than 1/10th that of ordinary dry cells). A circuit diagram and short explanation of the stabilizer circuit are given in the digest on page 164.

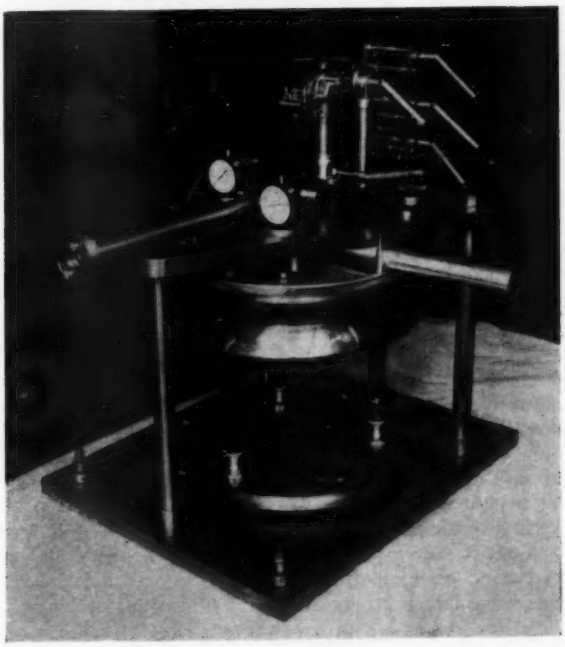
A joint discussion of the three papers was opened by Professor E. Bradshaw. The common link between the papers was high precision. It was suggested that the degree of stability in any context should always be expressed in parts in 10^6; this gave a clearer mental picture than either percentages or lower powers of 10.

With reference to Mr. Bowdler's paper, some doubts were expressed regarding the validity of the word "absolute," in view of the use of compressed gas and the consequent need to measure its permittivity. Some controversy centred on the respective merits of compressed gas and a vacuum: whereas the latter avoided the question of permittivity, a gas leak was more easily remedied than a failure of vacuum.

One speaker referred to a shielded capacitor normally capable of being used for voltage measurements up to 1 000 kV and said that it had shown itself to be liable to flashover in relative humidities of the atmosphere higher than 50%; at 85% the flashover voltage was as low as 640 kV. This speaker strongly preferred a peak voltmeter, especially for measuring direct and very high alternating voltages, and for this purpose the author's device offered the most hopeful prospects. He therefore advised the author "to go away and design a voltmeter to measure higher and higher voltages—preferably peak voltages." An alternative design of voltmeter was described and illustrated by lantern slides, one of which is reproduced in Fig. 2. It was vacuum filled and had given trouble on that account. Its main feature was the use of two cylindrical insulators with a gap between the adjacent ends. By adjusting the gap the optimum flashover value was obtained. A value 75% higher than that of the single cylinder described in the paper was claimed.

Another speaker gave a warning that h.v. capacitors were liable to change their capacitance with voltage. He also postulated that a good test of accuracy is to

2 *A vacuum-filled disc-type absolute voltmeter withdrawn from its case and terminal bushing*



compare readings of two instruments differently constructed but claiming the same degree of accuracy. If the readings differ by more than that degree of accuracy, one of them is inaccurate; if the readings agree, both are correct.

Two speakers discussing Mr. Jervis's paper expressed some surprise that the contact-modulator amplifier was preferred to the galvanometer type. They did not agree that the latter was the less robust instrument and claimed good performance as regards both overload capacity and insensitivity to vibration under conditions more onerous than those of the author's application. But it was very desirable to have dynamic balance in the galvanometer with the mirror fixed within the coil, the coil free to rotate, and the suspension immersed in a liquid of the same density as that of the coil system. The contact-modulator type, on the other hand, was liable to contact wear, with the result that the stability quickly decreased.

Referring to the third paper, by Mr. Haine and Mr. Jervis, a speaker emphasized that current is not the only factor which determines magnetic field and suggested it would be more appropriate to resort to a nuclear magnetic probe in the field of the microscope itself. Another speaker suggested that, if there are special virtues in the electron-optical method, they should be made clear, with a view to the use of the method in the control of precision stabilizers. Furthermore, it might be worth while to produce a simpler tube than that designed by Mr. Haine for his special purpose.

The three authors replied briefly to the discussion, answering most of the direct questions and dealing with the controversial issues in a commendably impartial manner.

M. K.

Joint Meeting with the Radio Section

Unfortunately, owing to the appalling weather conditions, there was only a small attendance on the 4th January, 1955, to hear Mr. H. McGregor Ross present his paper entitled *Equipment of Instrumental Accuracy for Recording and Reproduction of Electrical Signals using Cinematographic Film*. A digest of the paper appears on page 164.

Mr. Ross explained that the equipment had been developed in collaboration with the Admiralty Signal and Radar Establishment for the recording and analysis of results of radar trials on aircraft. As a result of the application of this equipment the labour involved in analysing trials records has been very much reduced. He explained that although a system using variable density had at first appeared to be simple, after development it turned out to be as complicated as the standard variable-area system used in sound reproduction; the latter system has the advantage that no special processing of the photographic film is required.

A most convincing demonstration was given of the play-back equipment using a film on which a 50c/s sine wave had been recorded at a film speed of 1in/sec. This was played back, first at a speed of 1/10in/sec and then at a speed of 10in/sec, and the resulting signals at 5c/s and 500c/s were displayed on an oscillograph. The ease with which the speed was changed with accuracy from 1/10in/sec to 10in/sec was most impressive. Equipment for transcribing from film recordings of aircraft position on to a film already carrying radar data for use in an analogue computer was also demonstrated.

Mr. J. F. Coales, in opening the discussion, emphasized the vast amount of information that has to be recorded during aircraft trials of radar and other equipment, and said that, so far as he knew, no complete set of records had ever been fully analysed because of the excessive labour involved. The equipment demonstrated would certainly very much reduce this labour. Although a few years ago analogue computers were being widely replaced by digital computers, more recently it has been shown that there are engineering problems which digital computers cannot solve, and so interest in analogue computers has greatly increased again.

Mr. K. W. Thwaites was one of the originators of the scheme at the A.S.R.E. and was able to speak of actual experience of operating the equipment, which seems to have been in every way satisfactory. He stressed the advantage over other methods of recording that is gained by being able to interpret the record visually without the necessity for play-back equipment. It is a particular advantage that after exposure of the film a small piece, perhaps containing a calibration strip, can be cut off and developed immediately, before the whole film is sent away for processing.

Regarding applications, he mentioned the use of the equipment for determining the correlation between simultaneously occurring functions, and the possibility of its use for the recording of waveforms on film for test purposes; in the latter application the ability to alter the film speed is a great advantage, since it enables the mean frequency of the power spectrum of the test signal to be varied over a range whose limits are in the ratio of at least 100 : 1.

Mr. W. Bamford suggested that the equipment might be used for fault recording on electrical supply networks.

In replying, Mr. Ross answered a number of detailed points raised by Mr. Coales and offered some hope that, in conjunction with magnetic tape recording the equipment might be suitable for the application suggested by Mr. Bamford.

The Chairman, Mr. M. Whitehead, then called on Mr. C. W. Oatley, Chairman of the Radio Section, who eloquently expressed the gratitude of his Section for having been invited to attend, and the gratitude of the whole meeting to Mr. Ross for reading his interesting paper.

J. F. C.

SUPPLY SECTION

Cooling Towers and Economists

A meeting of the Supply Section was held on the 5th January, 1955, with Mr. J. D. Peattie in the chair,

to hear two papers on *The Economic Selection of Cooling Towers for Generating Stations* by Mr. G. F. Kennedy and Mr. P. H. Margen, and *The Application of Friction/Heat-Transfer Correlations to Cooling-Tower Design* by Mr. Margen. The meeting was well attended, considering both the rather specialized subject, and the weather, which was more favourable for cooling-tower performance than human comfort. Both papers were lucidly presented, the first by Mr. Kennedy and the second by Mr. Margen. A digest of the papers appears on page 166.

Mr. F. H. S. Brown opened the discussion and said he was in general agreement with the trend towards smaller cooling towers. He also fully supported the authors' proposal to make use of the cooling capacity of rivers whenever possible. The rivers of this country were a natural asset which should be fully utilized, and this could be done without interfering with amenities. Mr. H. Chilton emphasized that the friction/heat-transfer correlation in Mr. Margen's paper should be regarded as a special case and was not necessarily of general application. He also suggested that it might be possible to improve heat transfer without a corresponding increase in friction. Economics loomed large in the discussion, but the pitfalls of the purely economic approach were stressed. Mr. B. Wood, after defining an economist as someone "who draws a straight line from an unwarrantable assumption to a foregone conclusion," said he trusted simple arithmetic more than advanced mathematics in assessing a design. He welcomed the use of turbine-exhaust heat loading as a design parameter but pointed out that it need not necessarily increase with machine size. Mr. G. J. Williamson stressed the practical limitations of available materials and suggested that it was best to make a good, sound, mechanical design first and work out the economics afterwards.

Additional experimental data were presented from the chemical industry by Mr. Williamson and from the B.E.A. Research Laboratories by Mr. H. J. Lowe.

Mr. B. Donkin discussed the use of cooling towers under tropical conditions, and pointed out that at Rangoon, for example, with a river temperature of 85°F and an atmospheric wet-bulb temperature 7° lower, cooling towers could be used without any loss of efficiency and sometimes with additional constructional advantages.

Reverting to the economic theme, Mr. D. Clark recalled a case in which it was shown that it would be economic to install an additional pump. A further application of the same argument showed that a second pump would be justified, and then a third—and so on up to 435 pumps, when the whole output of the station would have been required to drive the pumps. Mr. Clark also referred to the difficulties experienced in using rivers for cooling, and mentioned that in one instance a maximum limit of 60°F had been made a condition of consent when the river temperature attained 70°F in summer under natural conditions. Finally, Mr. C. G. Phillips, after referring to certain mysterious installations for a mysterious Ministry, suggested that air cooling might have advantages over water cooling for power stations.

Mr. Margen replied to the discussion as fully as time allowed, and Mr. Peattie proposed a vote of thanks to the authors. J. S. F.

Sealed Transformers

At the meeting on January 26th, the Chairman, Mr. J. D. Peattie, first welcomed three guests from abroad and then called on Mr. E. B. Franklin to present his paper on *Sealed Transformers*.

The author dealt mainly with transformers which are of normal construction but are sealed, and provided with a vessel or expansion space large enough to limit the gas pressure to a reasonable value. Nowadays the gas is usually nitrogen. The increase of pressure with temperature rise is less than expected owing to some of the gas passing into solution in the oil. Formulae have been developed by the author for maximum and minimum pressures, and at the meeting the creation of a negative pressure was explained and discussed. The oil with gas in solution has a lower electric strength, particularly under certain conditions of the cooling cycle. Mr. Franklin's conclusion is that the chief source of trouble in such transformers is this negative pressure.

The discussion covered a wider field than the paper, and many speakers emphasized the undesirability of restricted breathing, such as could occur with an imperfect gasket on a sealed transformer of this type, or with an arrangement of high- and low-pressure valves. Some speakers did not think a reduction in electric strength of the oil, of the order stated, mattered much, but they were rightly rebuked by a cable specialist, who pointed out that in that event the insulating materials concerned were not being used to the best advantage, and that they were much more highly stressed in cables.

Much information on the lowering of the electric strength of the oil was provided by speakers—generally in agreement with the author's figures, though he was challenged on his correlation figure for infinite-time breakdown compared with the one-minute value. Some details were also provided of experiments which are in process in the Midlands Electricity Board.

The economics of the subject were only lightly touched upon; and it appeared that the paper was somewhat exploratory but might be of assistance theoretically when transformers were designed with greater electric stress imposed on their insulation. L. H. W.

FARADAY LECTURE

Mr. Terroni Captivates a Large Audience

Nearly 2 000 people gathered at the Central Hall, Westminster, on the 27th January, 1955, to hear Mr. Terroni deliver the Twenty-Sixth Faraday Lecture on *Courier to Carrier in Communications*. This is believed

Roman mail-chariot

A mosaic illustration from a film shown at the Faraday Lecture

to be the largest attendance at any Faraday Lecture since the lectures began in 1924–25.

Mr. Terroni is well known to many members of The Institution through his work for the Mersey and North Wales Centre, of which he was Chairman in 1948–49, and through his long association with the Automatic Telephone and Electric Co. In his lecture Mr. Terroni began by tracing the history of methods of communication from ancient times to the present day. A cartoon film in colour, prepared by the producers of the film *Animal Farm*, depicted 2 500 years in the history of communication from Egyptian hieroglyphics on tablets to the development of the automatic telephone exchange. The film made a most fitting reference to Michael Faraday.

The principles of the dialling telephone and the switching equipment in a telephone exchange were next demonstrated on a special panel with a two-motion selector connected to lamps representing contacts on the selector, which thus allowed the dialling of different numbers to be displayed. Mr. Terroni next illustrated the use of a magnetic drum which acts as a storage device, and he used a large map with lamps along the various routes from London to the different Local Centres to show the way in which alternative routes could be selected automatically by the magnetic drum, when the normal route was blocked by excessive traffic or a failure from some cause. The failure of one of Mr. Terroni's assistants to follow out his dialling instructions presented the lecturer with an unrehearsed opportunity of demonstrating that "the machine is always right."

Mr. Terroni next considered the development of multi-channel communication, and a record of a deep voice and a high-pitched voice in duet was used to show how speech could be transferred to different parts of the frequency spectrum. This led to what was perhaps the most arresting demonstration of the evening: a mechanical model showed most clearly and effectively how three separate conversations could be simultaneously carried over the same circuit. The three conversations were represented by three tubes of white balls, which, after emerging from "mouths," were passed through "paint pots" that changed their colours to red, blue or yellow. Next they travelled down a common tube, at the far end of which were light filters and detectors that sorted the colours into their appropriate channels so that each "conversation," as depicted by the coloured balls, reached the correct "listener." This demonstration received a tremendous ovation.

A number of coloured panels were used to give a clear explanation of propagation through the ionosphere, and this phenomenon was demonstrated with great effect by a model in which metal sheets were used to act as reflectors in space. The model showed also the directivity of short waves and the fading effects which are experienced.

The lecture concluded with a specially-prepared documentary film, which traced the path of a telephone call from Birmingham to New York. This was treated in much greater detail than is usual in films of this type, and one seemed actually to travel with the call through every stage of its progress from the caller in Birmingham, through the local exchange, along the cables beneath the pavements and roads, to London, and then onwards over the Atlantic to the New York exchange.

That Mr. Terroni was able to hold the undivided attention of his audience for 90 minutes is sufficient indication of the high standard of his lecture, and the spontaneous applause which broke out on many occasions served to show how well it was received.

EDINBURGH, GLASGOW AND INVERNESS

SCOTTISH CENTRE

At a meeting of the South-East Scotland Sub-Centre in Edinburgh on the 21st December, 1954, Mr. J. W. Moule read an informal paper on *Floor Warming*. After referring to very early Korean and Roman floor-warming schemes, Mr. Moule described modern electrical methods, which have been pioneered very largely in Scotland. Ordinary 240-volt insulated heating cables are laid in concrete, the cables being in thermal contact with an embedded wire-mesh screen to give a uniform heat distribution over the floor surface. With a floor temperature of about 70°F a nearly uniform room temperature of 60–65°F can be achieved; the heat-storage capacity of the floor enables the temperature to be maintained for 12 hours or more after the current is switched off, so that off-peak tariffs can be used. Although running costs may be greater than with solid fuel the saving in capital charges more than outweighs this. A very lively discussion was opened by Mr. W. S. Primrose, also a pioneer in the subject, and continued by a large number of speakers, including members of the Architectural Association. The general conclusion reached seemed to be that floor warming is eminently suitable for many types of commercial building but less practicable for small dwelling-houses.

Informal meetings have recently been held by both

the South-West and the South-East Scotland Sub-Centres. In Glasgow on the 12th January, 1955, Mr. W. S. Wood read a paper on *Servo Machines*, in which he described rotating amplifiers and illustrated the common basis of all such types of machine; beginning with the separately-excited generator, Mr. Wood considered its characteristics, with particular reference to saturation and feedback; this led to a description of other types of machine, including the Metadyne, Amplidyne, Rototrol and Magnavolt.

In Edinburgh on February 1st the following three short papers on computers were read: *Some Aspects of the Design of General-Purpose Digital Computers* by Mr. B. W. Pollard; *The Design of Navigational Computers* by Mr. R. A. Sheppard; *The Use of Computers to Control Mechanical Operations* by Mr. D. T. N. Williamson. Mr. Pollard gave a broad survey of the digital-computer field, Mr. Sheppard described some of the essential components of an analogue-type of computer, and Mr. Williamson summarized the application of computers to the automatic control of machine tools. A very full discussion followed, and the attendance of 87 was almost a record for the Sub-Centre.

On January 31st the South-East Scotland Sub-Centre held, at the Charlotte Rooms, Edinburgh, a most successful joint dance with the East of Scotland Association of The Institution of Civil Engineers. About 150 members and guests were present, including many members of the respective Students' Sections. It is hoped that this is the first of many joint dances.

The Scottish Centre are looking forward with great pleasure to the Summer Meeting of The Institution, which is being based on Inverness during the week beginning June 6th. It will give members the opportunity of seeing not only some of the finest Scottish scenery (and the Loch Ness monster) but also much of the valuable work being done by the North of Scotland Hydro-Electric Board. In view of this visit the usual Summer Meeting of the Scottish Centre will not take place in 1955. E. O. T.

EXETER

SOUTH-WESTERN SUB-CENTRE

Snow in the Power Station

The Sub-Centre was honoured on the 18th January, 1955, by two distinguished visitors, Sir George Nelson, Vice-President, and Professor G. H. Rawcliffe, Vice-Chairman of the Western Centre. The Clerk of the Weather was, however, unimpressed by the importance of the occasion, and heavy snow fell in the south-west during the morning. Many members travelling long distances to the meeting, which was held in Exeter, failed to reach their objective. At a Committee meeting held during the morning a temporary Chairman was appointed, since neither the Chairman nor either of the Vice-Chairmen had been able to reach the meeting. However, Mr. Flower, the Past-Chairman, was able to fight his way through in time for the second course of lunch and presided over the main meeting in the afternoon.

Sir George Nelson, after conveying the good wishes of the Council to the Sub-Centre, spoke of the important part engineers were playing in the application of science for the benefit of peoples the world over. He also pointed to the professional status that membership of The Institution carried, and expressed the hope that all qualified to do so would seek full membership.

The paper on this occasion was *Some Design Features of the Semi-Outdoor Power Station at Ince* by Mr. F. H. S. Brown, which evoked considerable discussion. The author dealt with many questions and perhaps allayed some of the doubts and fears that were expressed about outdoor plant in the English climate. The importance of this experimental station to manufacturers in the export field was also brought out.

Mr. A. L. Keet expressed the appreciation of the meeting, and, after fortifying themselves with tea, members set out to battle their way homewards through wintry conditions which forcibly renewed their previous doubts about outdoor power stations. R. C. B.

HULL

DISTRICT MEETING

Forty-two members were present at the second District Meeting at Hull held on the 2nd December, 1954, when Mr. P. M. Hollingsworth and Mr. P. A. Raine presented their paper entitled *Aluminium-Sheathed Cables*, which was illustrated by lantern slides. Mr. Hollingsworth read the paper and Mr. Raine answered the questions that eight local members raised in the lively discussion. Thanks to the authors were expressed by Mr. W. S. Milner, the convener of the Hull District Meetings, who was in the chair; he pointed out that considerable local interest in this paper had been shown. J. L.

LEEDS

NORTH MIDLAND CENTRE

The work of the session has continued under the able leadership of the Chairman, Mr. W. A. Crocker, who presided, on the 2nd November, 1954, over a meeting in Leeds of 50 members and guests. The Centre were glad, on this occasion, to welcome four new Corporate Members. At a pleasing ceremony, the Chairman next presented to Dr. T. G. Bridgwood, the former Honorary Secretary of the Centre, a copy of *The History of The Institution* together with a Certificate of Office, making fitting reference to the work which Dr. Bridgwood had done for the Centre, until a breakdown in health, from which he is now happily recovered, caused him to resign. Dr. Bridgwood in his reply expressed the pride and pleasure which this presentation gave to him. The paper entitled *Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies on*

2nd June, 1953, was then read by Mr. M. J. L. Pulling and Mr. F. Williams. This proved to be a fascinating account, profusely illustrated, of a subject dear to everyone's heart, and the many technical problems aroused an interesting discussion led by Dr. G. N. Patchett and followed by six other members. A vote of thanks to the authors, which was proposed by the Chairman, was carried vociferously.

On November 16th, before 40 members and guests, the Chairman introduced Dr. K. J. R. Wilkinson, who presented his paper entitled *Measurements of the Winding Resistance of a 132kV Power Transformer in Service*. This very unusual subject greatly intrigued those present and stimulated a lively discussion opened by Professor G. W. Carter and followed by five other members. The meeting's thanks and appreciation were admirably expressed by the Chairman in calling for a vote of thanks.

The Annual Dinner of the Centre was held at the Queen's Hotel, Leeds, on November 19th, when members were delighted to welcome the President and the Secretary of The Institution. The 220 members and guests who attended listened keenly to the excellent speeches. Lt.-Cmdr. G. W. Wells, R.N. (Ret.), proposing the toast of "The Institution of Electrical Engineers," referred in a humorous vein to the multiplicity of electrical inventions to-day, and he closed by saying how fortunate we were to have Mr. Eccles for our President. When replying, the President remarked on the growth of the Centre, and went on to say that "we must put ourselves in the premier position in the world of technology." He appealed for a more generous attitude to the problem of overcoming the lack of science teachers. The Deputy Lord Mayor of Leeds, Councillor A. Smith, next proposed the toast of "The North Midland Centre," and paid tributes both to the electrical supply industry and to the research carried out by the electrical industry as a whole. The Chairman, Mr. W. A. Crocker, in replying, congratulated the authors of Institution papers on their originality; in his speech he deprecated the lack of an engineers' club in Leeds.

The toast of "Our Guests" was very ably proposed by Mr. G. Caton, immediate Past-Chairman, who said that "life would be dull indeed without our friends"; with many fitting references to the distinguished guests present, he coupled the toast with the name of the Rev. T. H. Tardrew, Canon Residentiary of York Minster, who thereupon replied in a very humorous speech, which closed on a serious note: "For every scientific advance we must strive for a moral advance to balance." The evening continued with many a laughing quip, after those at the dining-tables had broken into chatting groups.

On December 7th the Centre welcomed a Vice-President of The Institution, Sir W. Gordon Radley, to the meeting of 90 members and guests. During a short speech Sir Gordon said that he brought the best wishes of the Council to the Centre, and continued at the request of the Chairman to welcome one new Corporate Member. Mr. F. H. S. Brown then presented his paper on *Some Design Features of the Semi-Outdoor Power Station at Ince*. This was a most interesting report on what proved to be a highly controversial subject. The discussion opened by Mr. J. R. Rylands and continued by seven other members was extremely lively and interesting.

NORTH MIDLAND UTILIZATION GROUP

At the second meeting of the session, on the 23rd November, 1954, at Leeds, before 29 members, the Chairman of the Group, Mr. N. S. Goddard, introduced Mr. C. G. L. Morley and called on him to present his paper entitled *Electric Lifts in Post-War Housing*. Mr. Morley dealt with the many new developments and lift techniques in L.C.C. housing schemes since the Second World War. A spirited discussion was opened by Mr. B. Pirie, who was followed by six other members.

J. L.

NORWICH

DISTRICT MEETING

The third District Meeting of the session was held at the Assembly House, Norwich, on the 19th January, 1955. The Chairman, Mr. J. A. Sumner, first gave a brief report on the meeting of the East Midland Centre Committee which he had attended at Loughborough on January 11th, when the final arrangements for the formation of the East Anglian Sub-Centre were considered and agreed. He next introduced Mr. K. J. Cook and Mr. E. Claxton, and asked them to read the paper entitled *The Electrification of the Manchester–Sheffield–Wath Lines, Eastern and London Midland Regions, British Railways*. Mr. Cook is joint author of this paper with Mr. J. A. Broughall, who, unfortunately, was unable to be present owing to illness. Mr. Claxton kindly took his place.

This paper is of wide general interest and proved to be ideal for a district meeting, where the members represent various aspects of the engineering world. Both speakers took part in the reading of the paper, and each in turn answered with great competence and charm the subsequent questions. These carried the meeting to a rather late hour and would have extended it even further had not the Chairman felt compelled to bring the discussion to a close. A vote of thanks to the speakers was proposed by Mr. E. Hoare.

J. A. S.

OXFORD

DISTRICT MEETING

A Great Future

A lecture on *The Future of Electronics in Industry*, delivered by Mr. E. R. Davies, attracted 65 members and friends to the third informal District Meeting of the session, which was held at the District Offices of the Southern Electricity Board in Oxford.

Mr. Davies said that only about 2% of the total output of the electronic industry is devoted to industrial application; the remainder is divided between defence, communication, domestic radio and television. He forecast a great future for the use of industrial electronics, and illustrated his lecture with lantern slides showing the uses of induction and dielectric heating, particularly with regard to the hardening of steel shafts, mushroom valves, and the stitch welding of plastic materials.

The use of the ignitron and Emitron for the control of a.c. and d.c. supplies was illustrated, and Mr. Davies indicated suitable circuits for the automatic speed control of motors for paper- and cable-making machinery.

Of particular interest to the supply members present was the working of an electronic insulation tester that was capable of measuring insulation readings at voltages up to 10kV. Mr. Davies explained the action of the limiting-diode circuit to prevent the destruction of the equipment, in the event of the breakdown of the specimen under test.

There were numerous reasons, he said, for the slowness of manufacturers to adopt electronic technique, some being that there was a mistaken idea that the apparatus was not reliable, that specialists were required for fault location, and that the initial capital outlay for the equipment was high. Regarding this outlay, Mr. Davies said that the resulting increase in production justified the cost. He mentioned that the printing and motor industries have been quick to grasp the advantage of adopting electronic processes, and that a new generation of engineers is designing components that are more easily manufactured by such aids.

After the interval for refreshments, Mr. Davies had a busy time answering the numerous questions, and many useful contributions were heard from the industrial members present. A vote of thanks to Mr. Davies for his lecture was proposed by Mr. J. E. Bown and enthusiastically supported. G. Z.

READING

DISTRICT MEETING

On the 17th January, 1955, the Chairman, Mr. H. Willott Taylor, welcomed to Reading some 40 members and visitors from as far away as Hove—to hear Mr. S. J. Little and Mr. H. Fielding, of the Post Office, give a talk on *Post Office and Power Overhead Lines—New Methods of Guarding*. The authors also showed a film illustrating high-voltage power-line dropping tests, and lantern slides of both old and new methods of protecting P.O. circuits, including one of a form of joint construction erected in 1909. The authors gave a most authoritative and interesting résumé of the origin of the Postmaster General's requirements, beginning with the Telegraph Act of 1878.

In 1952 the Area Boards approached the P.M.G. with the request that the heavy cost to the supply industry of providing protection should be examined. In support of this request they gave particulars of the number of power/Post Office crossings involved during the previous 20 years, their operation and their approximate cost. As a result of this information the P.M.G., in conjunction with the Southern Electricity Board, arranged for a series of dropping tests to be carried out at a site near Crowthorne, Berkshire, and the film of these tests illustrated very convincingly that, in the unlikely event of a $0{\cdot}2\text{in}^2$ copper conductor breaking and falling across only two p.v.c.-insulated P.O. wires, no damage would be caused to either the P.O. wires or P.O. plant. These tests convinced the P.M.G. that it would be quite safe for bare high-voltage conductors to cross above p.v.c.-insulated P.O. circuits, and subsequent tests carried out in a similar way at the Home Counties Regional Training School, Bletchley, confirmed that a minimum thickness of 30 mils of p.v.c. would be sufficient to give protection to low- or medium-voltage line crossings.

After a most informative discussion, in which questions on all forms of protection required by the P.M.G. were discussed, the Chairman called upon Mr. Siviour to propose a vote of thanks to the authors. In the course of his speech Mr. Siviour mentioned that he had been most active in discussions with the Post Office from the infancy of overhead distribution, and was himself responsible for the erection in 1909 of the joint construction referred to above. T. E. R.

STAFFORD AND STONE

NORTH STAFFORDSHIRE SUB-CENTRE

Two related papers of considerable general interest were read at Stafford on the 22nd November, 1954. These were *Short-Circuit Forces on Turbo-Alternator End-Windings*, by Mr. J. B. Young and Mr. D. H. Tompsett, and *The Electrical Measurement of Steam-Turbine Rotor Movements, with special reference to the Operation and Design of Modern Power Plant*, by Mr. J. L. Ashworth, Mr. J. S. Hall, and Mr. A. H. Gray. A very active discussion of the two papers was opened by Mr. J. Barr. Dr. E. R. Patrick, in proposing a vote of thanks to the authors, said that the two papers fitted together well and were not encumbered with mathematics. The developments described in the two papers made a major contribution to the solution of the difficulties attending the starting, running and testing of large sets. He thought the authors were to be especially congratulated on the high-speed film which showed so clearly the movement of the alternator end-connections under short-circuit conditions.

Members of the Sub-Centre have learnt with regret of the resignation from the Committee of Col. C. E. Calveley, the immediate Past-Chairman, on leaving the district to take up new duties at the London Headquarters of the Post Office Engineering Department. The work he has done for the Sub-Centre is deeply

appreciated by the members and they wish him every success in his new post.

The sixth Annual Dance, held at the Crown Hotel on November 26th, again proved to be a most enjoyable and successful function. During the evening, Mrs. J. M. Ferguson gracefully presented prizes to the winners of the spot waltz and other events, and Mr. W. E. Darby as M.C. enlivened the proceedings in his own inimitable way. The Chairman, in a brief speech, thanked all who had assisted in the arrangements.

As the paper on *Aluminium-Sheathed Cables*, read by Mr. P. M. Hollingsworth and Mr. P. A. Raine at Stone on December 13th, seemed likely to interest many of the members of the Local Centre of the Institution of Post Office Electrical Engineers, they were invited to the meeting. Although the attendance was poor as a result of very bad weather, an unusually active discussion, opened by Mr. A. E. Jemmeson, followed the reading of the paper and continued around the many exhibits after the meeting was formally closed. A vote of thanks to the authors was proposed by Mr. P. D. Gilbey, who said that while considerable experience had been gained with lead-sheathed cables, these were not entirely free from corrosion in all circumstances; polythene sheathing over the lead was now being adopted in a manner similar to that referred to in the paper for aluminium-sheathed cables. It was pleasing to know that we were at least on level terms with other countries in developing the use of aluminium in cable-making.

L. G.

NEWS *from abroad*

HERE AND THERE

Mr. R. M. Charley, who is in Australia on the business of his company, addressed a meeting of members at Brisbane on the 10th February, 1955, on *Transformer Design and Associated Details*. Mr. A. W. Lineker, the Council's Oversea Representative for the Transvaal, had unexpectedly to visit Britain recently on business. On the 3rd February, 1955, he attended, by special invitation, a meeting of Council and was also present at an informal Dinner which the Council held after the Ordinary Meeting on that date. Mr. F. H. Sharpe, who serves on the Oversea Activities Committee, is now visiting India and will later be spending a few days in Burma, where it is hoped that it will be possible for him to address local members. Mr. Sharpe will also be visiting Bangkok, in which there are at present three members of The Institution, whom he hopes to meet. Mr. C. E. H. Verity, of the British Electricity Authority, left for Pakistan and Australia on the 22nd December, 1954. He stayed for three weeks in Karachi, where he addressed a meeting of members, before going on to Australia, for discussions with the New South Wales Electricity Commission. Arrangements have been made for him to address a joint meeting in Sydney of Members of The Institution and The Institution of Engineers, Australia, on *Modern Trends in Power Station Construction in Great Britain.*

CEYLON

CEYLON OVERSEA BRANCH

In December, 1954, for the first time on record, a joint meeting took place between the Ceylon Oversea Branch and the Ceylon Medical Association. The meeting was addressed by Mr. S. M. Pocock, who is in Ceylon under the Colombo plan to advise the Government of Ceylon on electromedical apparatus.

In his lecture Mr. Pocock dealt first with historical aspects of the development of electricity in medicine and then gave some detailed descriptions of recent electromedical apparatus, such as the electro-encephalograph and the electrocardiograph. He also referred to electro-convulsion therapy for the treatment of mental patients and described recent developments in electron-microscopy. At the end of his lecture Mr. Pocock answered a number of questions on the electron microscope, safety measures in the use of electromedical apparatus, and the life of valves fitted in such apparatus.

A vote of thanks, moved by Professor R. H. Paul, Chairman of the Branch, and seconded by Dr. Nimalasuria, was carried with acclamation.

MALAYA

SINGAPORE/MALAYAN JOINT OVERSEA GROUP

From a recent issue of the Bulletin of the Singapore/Malayan Joint Oversea Group that has been received in London, it is clear that the Group is most active at present. Apart from the usual meetings an excellent visit took place on the 11th December, 1954, to the Malayan Railway Workshops at Sentul, Kuala Lumpur. A small party was held on November 26th to meet Mr. and Mrs. H. J. F. Gourley. Mr. Gourley is a Vice-President of The Institution of Civil Engineers, and he and Mrs. Gourley were spending a few days in Singapore on their way home from Australia. The programme for the first quarter of 1955 has included two meetings at Kuala Lumpur and two in Singapore.

QUEENSLAND

By courtesy of the Deputy Director of Posts and Telegraphs, Mr. C. Faragher, members in Queensland have been able to inspect the new mechanical cancelling and mail-sorting plant which has recently been installed at the General Post Office, Brisbane; it has been constructed mainly by Post Office engineers. Twenty-five members visited the plant on the 14th October, 1954, and they were also given an opportunity of inspecting the latest developments in telegraphic communication. This visit was particularly instructive, since mechanical mail-handling plant is new to Australia.

November 19th saw members joining with members of the Brisbane Division of The Institution of Engineers, Australia, in a joint meeting which was held in connection with Sir John Hacking's visit to Australia. The meeting, which lasted for two-and-a-quarter hours, took place in the Engineering Department of the University of Queensland, and there were present some 60 members of the two Institutions and their friends. Mr. Just was in the chair and he cordially welcomed Sir John, who in return expressed his pleasure at being present and conveyed a message of greetings from the President and Council in London. He then addressed the meeting on the construction and operation of generating stations and transmission lines in Britain, referring to thermal and several other forms of generation, including the use of nuclear power.

After Sir John had replied to questions, a vote of thanks was moved by Mr. A. McCulloch and seconded by Mr. J. E. Kinder.

RHODESIA

On the 8th January, 1955, some 50 members of The Institution, living in and near Salisbury, had the privilege of welcoming Mr. J. R. Beard at an informal cocktail party arranged by them specially for the occasion. Seldom does so distinguished a member visit Rhodesia, and members were grateful for the time he spent with them.

A high-light of the occasion was the news received on the same day by Mr. Beard that the Council had elected him an Honorary Member. In offering him their congratulations and drinking his health in the approved Rhodesian manner, members felt they had stolen a march on their colleagues elsewhere by being the first to do this in person.

A. B. C.

WESTERN AUSTRALIA

Recent activities of the Western Australia Oversea Committee have included three joint meetings with the Perth Division of The Institution of Engineers, Australia, at which the following papers were presented: *The Design and Construction of the South Fremantle Power Station*, by Mr. F. C. Edmondson; *Cocos Island Airport Construction*, by Mr. F. W. Dawson; *The South West Power Scheme*, by Mr. F. C. Edmondson and Mr. J. B. Jukes.

WEST INDIES

It has become customary for members of the three Institutions—Civil, Mechanical and Electrical—in Trinidad to join together for a Dinner; the function has established itself as one of the more important in the calendar of social events in Trinidad. This year it took place at the Queen's Park Hotel, Port of Spain, on the 22nd January, 1955, and among the guests were His Excellency the Governor and Lady Rance, Lt.-Cmdr. J. Eastley, A.D.C. to the Governor, Mr. Osborne, Director of Works and Hydraulics, and Mrs. Osborne, Dr. A. L. Down, Chairman of the Trinidad Branch of the Institute of Petroleum, Mr. George de Nobriga, Chairman of the Trinidad and Tobago Electricity Commission, and Mrs. de Nobriga.

Sir Hubert and Lady Rance were met on arrival by Mr. K. W. Finch, Chairman of the Joint Organizing Committee, and Mrs. Finch, and Mr. D. P. J. Holbrook, the Secretary to the Committee. Trumpeters of the Police Band played a fanfare, which was followed by the National Anthem. Mr. Finch presented the Local Officers of the Institutions and other official guests to Sir Hubert and Lady Rance.

The toast of "The Institutions" was proposed by Sir Hubert, who suggested that parents in Trinidad, many of whom encouraged their children to take up such professions as medicine and law, might well consider engineering as an alternative for children that showed any inclination towards it.

Replying on behalf of the Institutions, Mr. Finch referred to engineering achievements in the colony. He mentioned specially the reinforced-concrete bow-spring bridge which is nearing completion at the end of the San Fernando by-pass, ship repairing and construction, the completion of the multi-channel v.h.f. radio link between Port of Spain and San Fernando, and the installation of the Belmont automatic telephone exchange.

Mr. W. Boyd, Chairman of the Caribbean Branch of The Institution of Mechanical Engineers, proposed the toast of "Our Guests," to which Dr. A. L. Down replied.

OVERSEA ATTENDANCE REGISTER

During the period 1st January to 31st January, 1955, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

ANGUS, J. HOUSTON (**Lagos**).
DAVIES, E. G. (**Durban**).
GLOVER, T. J. (**Australia**).
GURNEY, F. (**Bukuru, Nigeria**).
KIRBY, H. VERNON (**Gold Coast**).
REID, R. C. E. (**Trinidad**).
ROBINSON, G. H. T. (**Nigeria**)
SIDDAWAY, R. (**Singapore**).
STOCK, J. M. (**Kampala, Uganda**).
WESTLAKE, Sir Charles R. (**Kampala, Uganda**).

Journal I.E.E., March 1955

Technical Education and Training in Germany

K. R. Sturley, Ph.D., B.Sc., Member

Dr. Sturley, who is head of the B.B.C. Engineering Training Department at Evesham, has contributed this note on technical education and training in the Federal Republic of Germany. He draws comparisons between Germany and England that will be illuminating to those engineers unfamiliar with the German system of technical training.

THE remarkable recovery of the German industrial economy from the devastation of war was quite evident in 1952 on my first post-war visit to the country, and I wondered then how much was due to the German people's capacity for work, how much to their innate skill and how much to their methods of technical training. At the invitation of the Foreign Office in March, 1954, I was able to find an answer to some of these questions during a fortnight's study of the methods of industrial and technical training employed in Hamburg, Hanover and Berlin.

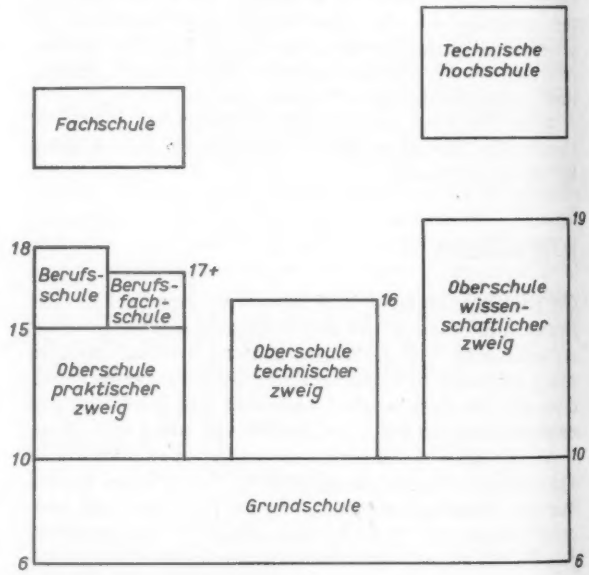
The German Educational System

In order to place training in proper perspective one must know something of the German educational system. It differs from the English system in that it is organized on a federal basis with control vested in the separate *Länder*, each roughly equivalent to an English county. There may be appreciable inter-*Länder* variations, and politics play an important part in appointments to headmasterships and the higher-grade educational posts. In spite of this it is possible to extract a pattern for the educational system, and the diagram represents an average progress chart.

Full-time education from 6 to 15 years and part-time education from 15 to 18 years are compulsory. The first four years (in some *Länder* six years) are spent in the *Grundschule* (primary school). Primary teachers, together with representatives of the secondary-school staff, determine the child's correct placing when he enters the secondary stage. As in England, three main streams of secondary schooling are recognized. The *Oberschule* (*Praktischer Zweig*) corresponds roughly to our Secondary Modern School and caters for children up to 15 years of age. The *Oberschule* (*Technischer Zweig*) bears some resemblance to our Secondary Technical School, and education ceases at 16; our Grammar School is paralleled in part by the *Oberschule* (*Wissenschaftlicher Zweig*), where the scholar may remain until 19, when he would normally take the only school examination, the *Abitur*. Successful completion of this examination, which caters for a wide variety of subjects from classics to modern languages and natural sciences, at a standard equivalent to the General Certificate of Education at Advanced Level, provides entrance to the university or to the *Technische Hochschule*. The absence of any kind of written examination (except the *Abitur*) during school life is in marked contrast to our system.

The scientific faculties of the universities in Germany deal only with the natural sciences. Applied science and technology are the concern of the *Technische Hochschulen*. University and *Hochschule* courses normally are of 4–5 years' duration, but a student, if he so desires, may take the first half at one place and complete it at another. Scholarships are very limited in number and low in value. A very large proportion of students have to exist in difficult circumstances. Some of the large industrial companies provide scholarships for promising employees; no "strings" are attached and there is only a moral obligation on the student to return to the firm that sponsors him.

From the diagram we see that there are four types of vocational institution. The most elementary is the *Berufsschule*, which mainly provides the part-time compulsory education for boys and girls between 15 and 18 years old. The purpose of the *Berufsfachschule* is to give full-time courses for students in the age range 16–19 in subjects for which there is no suitable apprentice scheme. The *Fachschule* trains mainly in the applied sciences such as engineering, and there are evening as well as full-time day courses, generally lasting three years. The bias is towards practice, and applications rather than fundamentals are the important feature. In the *Technische*



The German educational system

Hochschule teaching of fundamentals is stressed and standards are equivalent to those of an applied science department of an English university. Since these schools are of interest to us only in so far as they contribute to engineering training, their specific functions can best be shown when dealing with the various types of engineering recruit.

Craftsmen, Technicians and Engineers

In England we think of our skilled industrial staff in terms of the craftsman, technician and professional engineer. In Germany similar groups can be discerned, although there is more conscious emphasis on craftsmen and engineers than on technicians, who possess, as in England, a wide range of abilities. The highest-grade technicians are the *Ingenieure*, trained in the *Fachschule*; the next in ability are the *Techniker* (also trained in the *Fachschule*); and at a lower level there are technicians such as fault-finders, testers and repairers, who are often officially classified among the craftsmen though their training carries little real craft-work.

The Craft Apprentice

Let us look first at the craft apprentice: the majority of German children leaving school at 15 or 16 are apprenticed to a trade, even such work as butchery, chimney-sweeping, etc., being recognized as trades for an apprenticeship lasting three years. The *Handelskammer*, an employers' organization embracing small as well as large businesses, exercises strict control over all apprenticeships and ensures that a certain practical standard is reached irrespective of the size of an undertaking. Some 80% of the craft apprentices come from the *Praktische Oberschule* and the remainder from the *Technische Oberschule*. Vocational and intelligence tests are carried out by the labour exchange in order to aid selection by the smaller firms, but the larger industrial companies have their own tests by which they select the prospective apprentice some 4–5 months before he leaves school. In West Berlin, owing to political isolation, juvenile unemployment is much higher than in Western Germany and tests tend therefore to be more stringent. Thus one large electrical firm there checks dexterity by exercises in folding paper and bending wire to given shapes; checks hand control by providing an intricate pattern formed of parallel closely-spaced lines, which must be followed by pencil between, and without touching, the lines; and checks mechanical sense by demanding the dismantling and reassembly of a given mechanism. Memory is tested by allowing the candidate to read an instruction which he must repeat 30 minutes later; a drawing with measurements is shown and this must be reproduced 10 minutes later. All apprentices are given a book in which to record their work, a sketch is expected and the time taken for the work to be completed is noted. As an incentive, wall charts, which take into account conduct, quality of work and time spent, indicate the progress and placing of individual apprentices. Sometimes a wage premium is offered to outstanding boys. Practical examinations may occur each month for the first six months; thereafter they occur yearly. Unsatisfactory progress leads to a transfer to other work or to termination of the apprenticeship. The main lines of training are similar in all types of firms. Big companies have centralized schemes, some with a separate training workshop, others with a part or corner of the main factory. Of the 3–3½-year course, 1½ years are spent in foundation training at the bench and on machines in the training workshop, and one year is spent in the factory, where the apprentice is still under the full control of the training department. For the last half-year he is back in the training workshop preparing for the final examination. Some establishments favour apprentices making their own tools, others provide them. Most firms turn these recruits to simple production jobs as soon as they have gained some skill.

During his period of industrial training, until the age of 18, the apprentice must attend the *Berufsschule* for one day (8 hours) per week; one hour of this is devoted to cultural subjects, civics, etc., and the rest of the time to subjects bearing on the job he is learning, e.g. simple calculation, drawing, commercial or engineering procedure. No manual skills are taught because these are the employer's responsibility. The kind of vocational bias depends on the local industry, and the school authorities prepare the syllabus, which must be approved by the *Handelskammer*. Each school has a *Beirat* (school council composed of teachers, *Handelskammer*, trade unions and often parents) to advise on the implementation or amendment of courses. When a large number of small industries are served by one school, sub-committees are formed to look after sectional interests. Some companies have works schools which supplement the instruction given at the *Berufsschule* to the extent of a half-day.

To obtain the final Journeyman's Certificate the apprentice has to take a practical examination lasting about 20 hours, followed by a written and oral examination on his *Berufsschule* work. Two attempts may be made at the practical and theoretical examinations but a second failure in either means demotion to unskilled worker with no chance of recovery. First and second failures were said to average about 6% and 4% respectively. The practical test, conducted by the *Handelskammer*, is the same for the whole area over which this has jurisdiction. The apprentices take the examination at a works other than their own and are assessed under a number by representatives of the *Handelskammer*. Two possible avenues of promotion are open to the holder of the Journeyman's Certificate. He may proceed by good workmanship and an evening course at the *Berufsschule* to his *Meister-Prüfung* (Master's Certificate), which permits him to start on his own and to take apprentices or, if he is in a factory, to qualify as a foreman or as a teacher in the training department. Alternatively he may decide to attend a *Fachschule* and become the equivalent of our technician.

The Technician

Turning to the technician class we find that it is drawn from the best of the journeymen (mostly from the *Praktische Oberschule*), from the ranks of the boys who have left the *Technische Oberschule* at 16 and occasionally from the *Wissenschaftliche Oberschule* boys. The journeyman may decide to take a four-year evening course at the *Fachschule* to become a *Techniker*, or he may be subsidized by his firm in order to enter a three-year full-time *Fachschule* course leading to the title *Ingenieur*, the highest grade of technician. Generally he will need to complete two years in the factory after his journeyman's certificate before receiving financial help. The *Techniker* reaches a standard about equal to that of the Ordinary National Certificate and the *Ingenieur* to that of Higher National Certificate. Before the non-journeyman can enter the *Ingenieur* course, a two-year period of practical industrial training must have been undertaken as a *Praktikant*. During these two years (usually from 16 to 18 years of age) there will be special courses in German, mathematics and general science at the *Berufsschule*, in preparation for the entrance examination to the *Fachschule*. A typical programme for the two-year *Praktikant* would be six months' basic training at the bench, two months on lathe work, foundry work and on model-shop work, three months in small parts assembly, in complete assembly and in test room with short periods at welding and in the smithy. The three-year *Ingenieur* course at the *Fachschule* has six terms, each of 20 weeks, and most of the remaining time is taken up with vacation work in industry. It is possible (but is not often achieved) for a *Techniker* student to transfer to the *Ingenieur* course, the first five terms (evening) being equated to two terms (day), or the whole eight terms (evening) to three terms (day). The *Fachschul-ingenieur* is generally a useful member of the production staff, but he also finds an outlet for his gifts in design and development work; and sometimes in research, assisting professional engineers.

The Professional Engineer

And now to the professional engineer: the great majority of this group are graduates or *Diplom-Ingenieure* who have attended a *Technische Hochschule*. Conditions for entry to the latter are the *Abitur*, together with at least six months' industrial training as a *Praktikant*, and the works report is taken into account when acceptance is being considered. Before *Diplom-Ingenieur* status is awarded, a further six months' *Praktikant* training must be completed, generally during vacations. The 4–5-year *Hochschule* course is very thorough and the first 1½ years concentrate on the fundamentals of physics, engineering and mathematics. The final examination, which can be taken at any time after the completion of the course, is mainly oral. The lack of cultural background often shown by the engineer is appreciated and attempts are made to remedy this. They vary from special cultural lectures (about six per term) to the arrangements in the *Technische Universität*, Berlin, where 10–15% of student time in the early years is devoted to a study of humanities.

The scarcity of scholarships makes the lot of the impecunious student very hard, but not so hard as at the university, because it is easier for the *Hochschule* student to obtain vacation work in industry, and some of the larger industrial firms assist promising students during their *Hochschule* career. Some educational authorities pay part of the fees, but as a rule Germany lags far behind England in providing for her poorer student. This does not, however, reduce the number of applicants, since academic qualifications are given a very high place in German society.

A few of the best *Fachschulingenieure* may go on to the *Technische Hochschule*, but their general education must be good and their performance at the *Fachschule* outstanding. Since the *Fachschule* course has a practical bias and narrower scope it is not easy to obtain exemption from any part of the *Hochschule* course, so that the *Ingenieur* is rather old when he graduates as *Diplom-Ingenieur*. The *Diplom-Ingenieur* is generally employed in research, design and construction with *Ingenieure* (technicians) as assistants; he is seldom found on the factory floor but is often in higher direction.

Appreciation and Comparison

Any comments that one might make after a fortnight's study must naturally be treated with reserve, but the following points are perhaps worth stating.

Craft apprenticeship is very well organized and is of particular value in areas where small industrial concerns predominate. We in England can learn much from their experience; there is no evidence that the average standard of craftsmanship is any higher, but a far larger number of school-leavers are receiving vocational training of good standard. In contrast to the primary- and secondary-school-education period when examinations are unknown, the craft-training period seems to be exam-ridden.

In the training of technicians Germany can teach us little: indeed there is much to be learnt from us in the way of short-circuiting procedure and ensuring that the first-class apprentice, or *Praktikant*, has an opportunity of going direct to the *Hochschule*.

The two-year graduate training schemes organized by many of our large industrial firms appear to be in advance of the German method, which demands only six months' pre-graduate training followed by six months' vacation training.

There is nothing comparable to the scholarships available for the university education of the first-class English schoolboy, and it seems probable that most of the less fortunate German students are unable to benefit fully from their *Hochschule* courses because of financial straits. The *Technische Hochschule* method of training engineers does not appear to have any advantages over our more usual method of having an engineering faculty as part of a university.

CORRESPONDENCE

LETTERS TO THE JOURNAL ON ELECTRICAL ENGINEERING SCIENCE OR TECHNOLOGY ARE WELCOME. IN PARTICULAR, MEMBERS (AND OTHER AUTHORS) WHO ARE SUBMITTING A PAPER TO THE INSTITUTION ARE ASKED TO CONSIDER THE POSSIBILITY OF MAKING A BRIEF PRELIMINARY ANNOUNCEMENT BY MEANS OF A LETTER BEFORE THE PAPER IS WRITTEN. CORRESPONDENCE SHOULD BE ADDRESSED TO THE SECRETARY OF THE INSTITUTION AND MARKED "FOR PUBLICATION." A CARBON COPY OF EACH LETTER SHOULD BE INCLUDED.

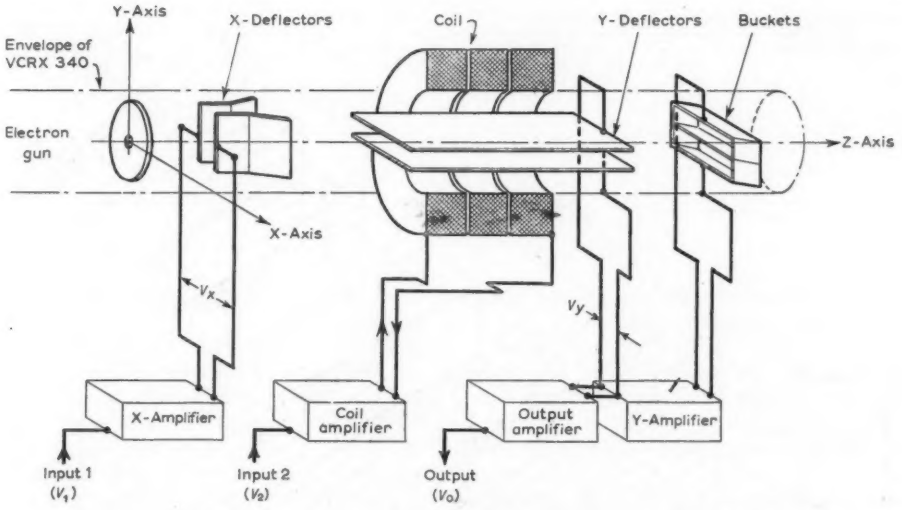
A Crossed-Fields Multiplier

From J. A. ROBERTS, B.ENG., *Associate Member*

In a recent Institution Monograph,[1] Deeley has described the application of a natural product law in a device for the accurate high-speed multiplication of two time-variant voltages of changing algebraic sign. In considering the further development of the method, he envisages—as indeed does the original patent specification—the use of a special tube to avoid the inconvenient and error-prone optical link required with a conventional cathode-ray tube.

Such a tube has in fact already been produced. After the original communication of Deeley and Mackay,[2] an independent investigation at the Royal Aircraft Establishment led to the production of a small bucket-tube, VCRX 340, and to the development of a multiplier unit based on this tube, as described below. A full account of the work has appeared as an internal publication of the Ministry of Supply[3] with limited circulation.

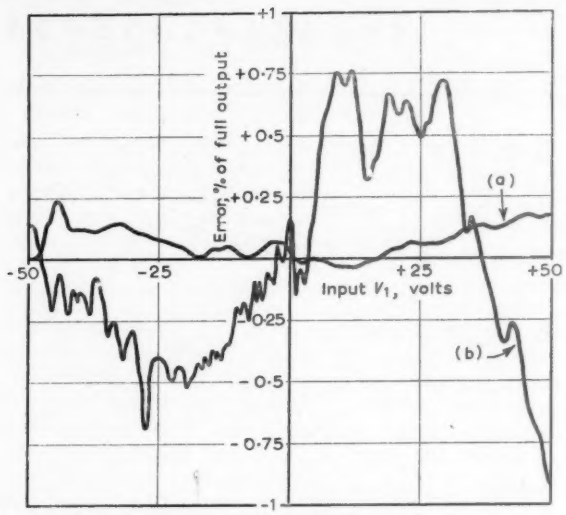
Fig. 1 illustrates schematically the employment of the VCRX 340 tube in the multiplier. The mode of operation is that described by Deeley. To recapitulate briefly, the electrons of the beam are given a transverse velocity v_x, proportional to one input V_1, applied to conventional deflector plates. An axial magnetic field H, proportional to the second input V_2, is produced in the space within the Y-plates. In the VCRX 340 tube, these are elongated to simplify the design of a coil with limited fringe fields. A pair of buckets, or, in later versions, a system of overlapping flat plates, replaces the fluorescent screen, and defines a line $y = 0$. The beam is "locked" to this dividing edge by feedback to the Y-plates, so that the Y-displacement of the beam at the buckets is maintained effectively zero. With an ideal uniform axial field confined to the Y-plates and having zero radial component, this condition implies equality of the forces acting on the electrons within the Y-plates. The electric field strength E_y is then a measure of the force v_xH, due to the electrons' motion across the magnetic field, and hence the voltage V_y, on the Y-plates is proportional to the product V_1V_2.



1 *Schematic of crossed-fields multiplier*

The errors of this version of the crossed-fields multiplier can be grouped under three headings: errors in the static calibration, frequency-sensitive errors, and noise. The static error has two principal components. The first arises because a bounded uniform axial magnetic field cannot be produced in the tube without a radial

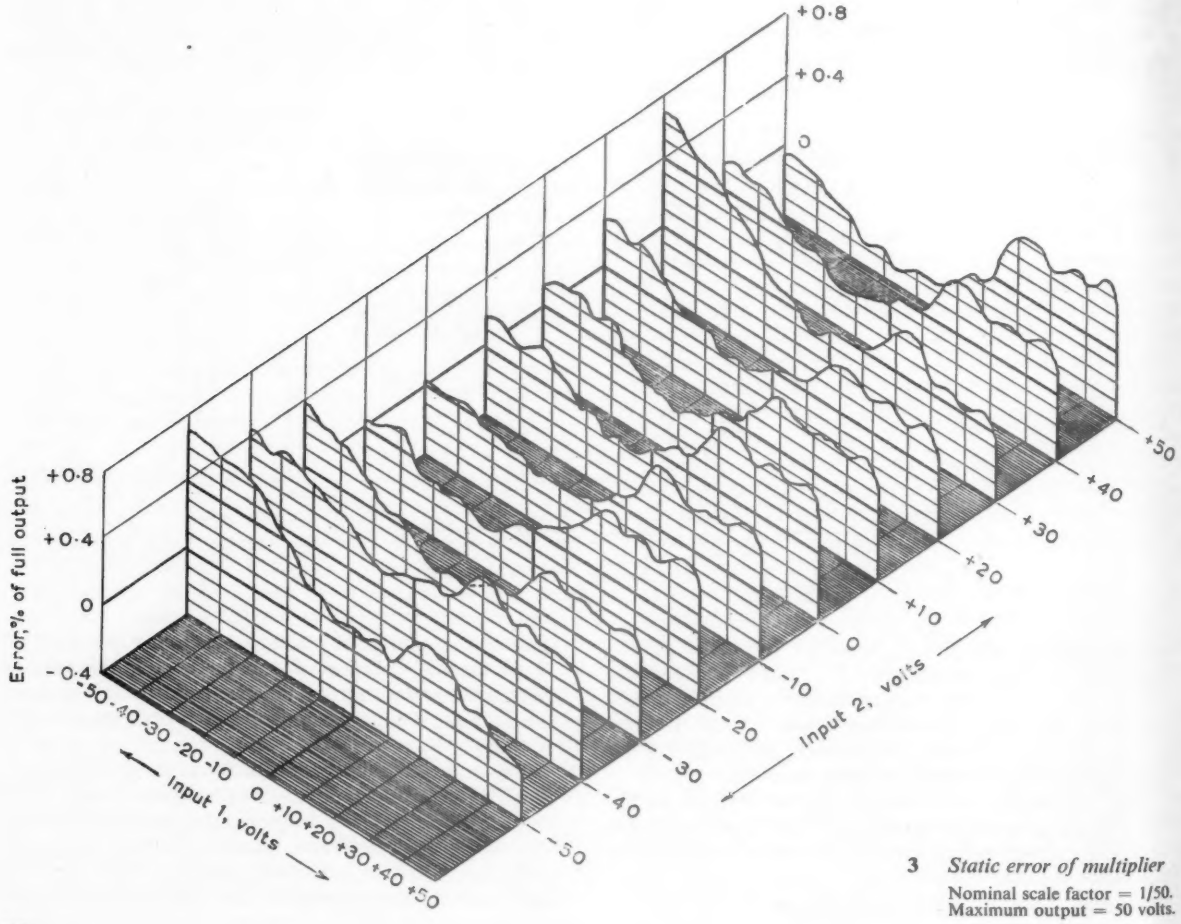
Mr. Roberts is at the Royal Aircraft Establishment.



2 *Typical edge-errors of the VCRX 340 tube*
(*a*) Good multi-plate tube.
(*b*) Average bucket-tube.

component; the method can never in fact achieve perfect multiplication. The effects of the radial component and of any extension of the axial field outside the Y-plates have been analysed[3] for various simple field configurations in the VCRX 340 tube. The fringe fields were shown to produce an error in scale factor reaching 1% of the weak-field value at field strengths between 10 and 20 gauss for the field configurations examined. With the compensated-coil system finally selected, the maximum field strength of 12 gauss leads to a maximum error in output of less than $\frac{1}{2}$% of full output.

The second major error arises because the line defined by the dividing edge is not precisely $y = 0$. Errors in the position of the edge and in tilt relative to the deflection axis of the X-plates are removed by adjustment of biases and of coil standing-current respectively. There is an error due to the irregular profile of the effective dividing edge, which varies from tube to tube. If there were no secondary emission from the buckets, the profile would be due to a mechanical error of 1/1 000 in. However, secondary emission from either bucket will modify the apparent edge profile. Retarding fields are arranged



3 *Static error of multiplier*
Nominal scale factor = 1/50.
Maximum output = 50 volts.

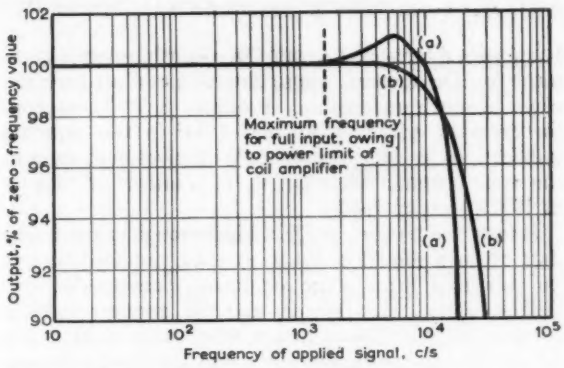
to control this emission and can often be adjusted to reduce the edge error.

About 40 experimental tubes have been made, in which the maximum edge error has varied from 2% of full output down to about ⅓%. Fig. 2 shows two examples of edge error in a poor tube, i.e. the output with V_2 zero and V_1 varied. The total static error is illustrated in Fig. 3 for the tube of Fig. 2.

This static error, normally between ±½% and ±1% of full output, is unavoidably associated with the tube, but the remaining errors of the multiplier are controllable in the design of the auxiliary circuits. Here the emphasis has been laid on economy of power consumption (a total of 40 watts) rather than high-frequency response. Nevertheless, owing mainly to the use of a highly efficient bridge circuit in the coil drive amplifier, full output can be produced up to 1·1 kc/s with negligible increase in error. The multiplier error at that frequency is virtually the static error (Fig. 4). The zero drift is normally between 20 mV and 100 mV (0·04% and 0·2% of full output) in any hour after warming up.

Several of these multipliers have now been in satisfactory operation for periods up to three years; apart from manual zero-setting, no adjustment is normally required, beyond that occasioned by tube changes, to maintain the static accuracy within ±½% of the initial condition, i.e. with total errors less than 1% of full output.

The VCRX 340 tube was produced by the General Electric Co. under the direction of Mr. L. S. Allard. Mr. D. C. Pressey of Southern Instruments was responsible for the design of the remainder of the multiplier. Acknowledgment is made to the Chief Scientist of the Ministry of Supply, and the Controller of H.M. Stationery Office for permission to publish this letter.



4 *Overall frequency response (measured)*

(*a*) Signal applied to input 2; direct current applied to input 1.
(*b*) Signal applied to input 1; direct current applied to input 2.

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(2) DEELEY, E. M., and MACKAY, D. M.: "Multiplication and Division by Electronic-Analogue Methods," *Nature*, 1949, **163**, p. 650.
(3) ROBERTS, J. A., and PRESSEY, D. C.: "A Cross-fields Multiplier." unpublished *M.O.S. Report*, April, 1954.

Dr. William Gilbert

From G. F. GAINSBOROUGH, PH.D., *Associate Member*

May I comment on some of the statements made about Dr. Gilbert on pages 14 and 15 of the January issue.

The weight of evidence does not support the statement that Gilbert was born in 1540. His memorial stone on the wall of Holy Trinity Church, Colchester, erected by two of his brothers, is inscribed to the effect that he died in 1603 "*aetatis sua* 63," and there is a portrait with the legend "1570 *aetatis* 30." These two pieces of evidence may not, of course, be independent. On the other hand, Dr. Gilbert was the first child of his mother's second marriage, and her first husband did not die until the spring of 1541. A horoscope for Dr. Gilbert in the Bodleian Library, probably dating from about 1577, gives the time of his birth as 2.20 p.m. on the 24th May, 1544; and the Oxford portrait represented by the engraving reproduced on page 13 of the *Journal* was inscribed "1591 *aetatis* 48," which meant that he was either 48 years old in 1591 or was in his 48th year. Also, the usual age for entry to the universities in those days was about 16: 14 was by no means remarkable for a brilliant boy, but 18 would need some explaining. Thus it seems clear that Dr. Gilbert could not have been born before 1542 or later than 1544, and since an astrologer would consider it useless to cast a horoscope without knowing precisely the time of the subject's birth it seems reasonable to accept the evidence of the document at Oxford.

The Oxford portrait, dated 1591, could not have been painted by Cornelius Jansen, who was not born until 1593 or 1594.

Gilbert survived the Queen not by a few years but by a few months. They both died in 1603. I do not think there is any evidence that he died in Colchester.

It must have surprised some readers to be told that the *versorium* with which Gilbert explored the magnetic fields of lodestones was an electroscope! There is confusion here between his *versorium magneticum* and his *versorium non magneticum*. The second was indeed an electroscope, but the first was an ordinary magnetic needle.

Reply to Dr. Gainsborough's letter from C. MACKECHNIE JARVIS, *Member*

I am very interested to read Dr. Gainsborough's comments on Dr. Gilbert, whose date of birth has been the cause of much uncertainty. Professor S. P. Thompson, for example, quotes 1540[1] and 1544[2] in two separate publications in 1903. Professor Wolf gives both dates in the same volume,[3] while Dr. R. T. Gunther[4] as recently as 1937 favoured 1540.

It may well be that, as Dr. Gainsborough suggests, the date of birth should be taken as 1544, provided we can be sure that there is no confusion between William Gilbert senior, the Doctor, and his younger half(?)-brother William Gilbert junior, who survived him. So far as the apparently late entry into Cambridge is concerned there are, of course, the two authorities quoted by Mottelay,[5] who state that Gilbert spent some time at Oxford, to which university he bequeathed his portrait (according to Thompson). If there is any truth in this, Gilbert's time at Oxford must have preceded his entry to Cambridge, where he spent some 11 years.

I agree with Dr. Gainsborough's remark about the period by which Gilbert survived Queen Elizabeth, and I apologize for the error. It is true that we do not know for certain where he died, but by implication[2] his death was from the plague. We know that the court left London and took refuge at Wilton, and there is contemporary evidence that many other people left the capital, so that it would not be unreasonable to suppose that Gilbert did the same. The fact that he was buried in the Church of Holy Trinity at Colchester does not appear to be disputed, and I feel that, had Gilbert died in London of the plague, his body would not have been transported 50 miles but would have been buried in one of the City churches.

I followed Thompson in attributing the portrait to Jansen, and unfortunately Harding[7] gives no indication of its origin. As Dr. Gainsborough points out, it could not have been painted *from life* by Cornelius Jansen (1590–1665), and having regard to Gilbert's position at court, a more reasonable attribution would be to Marc Gheerhaerts the younger (1561–1635), but this, in the absence of the portrait or other evidence, must remain a matter for conjecture.

In respect of the *versoria*, there has been no confusion in my mind, but my text suffers, perhaps, from over-simplification, for which I am responsible, in an endeavour to avoid pedantry. As Dr. Gainsborough says, Gilbert's pivoted-needle *versoria* were of two types, that with a magnetic needle being a magnetoscope, and that with a non-magnetic needle, an electroscope. The former was used in observations on lodestones and the latter in experiments with bodies "electrified" by friction.

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(2) THOMPSON, S. P.: "Gilbert of Colchester" (printed privately by S. P. Thompson, 1891).
(3) WOLF, L.: "A History of Science and Technology in the XVIth and XVIIth Centuries" (Allen and Unwin, 1935).
(4) GUNTHER, R. T.: "Early Science in Cambridge" (Oxford University Press, 1937).
(5) MOTTELAY, P. F.: "Gilbert of Colchester" (John Wiley, New York, 1892).
(6) Talbot and Cecil Papers at Hatfield House, quoted by S. P. THOMPSON in his "Gilbert, Physician" (printed privately in 1903), p. 28.
(7) "Biographical Mirrour" (Harding, London, 1795).

OBITUARY

ARTHUR DOUGLAS CONSTABLE

Arthur Douglas Constable, O.B.E., F.C.G.I., who died on the 12th November, 1954, at Weybridge, Surrey, was born on the 19th April, 1875. He received his technical education at the Central Technical College, London, under Professor W. E. Ayrton, and obtained a Diploma in Electrical Engineering. In 1895 he joined the India Rubber, Guttapercha and Telegraph Works Co., with whom he was engaged in submarine-cable testing. After serving with the Croydon Electricity Works as a shift engineer and later as a lighting engineer—and a short time with the Chatham and District Light Railway Co.—he entered the service of the Admiralty at Portsmouth Dockyard in 1903.

The Admiralty was then appointing its first group of electrical engineering officers, with Mr. C. H. Wordingham as Superintending Electrical Engineer, to deal with the gradually growing electrical installations in warships, and with large-scale electrification schemes in H.M. Dockyards at home and abroad. Mr. Constable assisted in this work—first at Bermuda until 1904, then at Gibraltar until 1913, when he was appointed as Electrical Engineer to the Admiralty in Whitehall. He remained there for the rest of his professional career, being appointed Assistant Director of Electrical Engineering in 1918, Deputy Director in 1922, and Director in 1934, a position which he held until his retirement in 1937.

During the majority of his service at the Admiralty he was engaged in problems of design of electrical equipment and systems for warships. He showed great ability, both in the larger supply and control problems and in the detailed design of intricate mechanisms; his influence over the whole field was very noticeable. Much of the equipment designed at the time bore the stamp of his personal work; it withstood the strain of the Second

World War and it is in use to-day in our older warships. Official files contain records of patents taken out by him over a wide field, including switch and control gear, cables, heating apparatus, secondary batteries, and machinery and machinery control systems for propulsion and other purposes.

His somewhat shy and retiring personality often masked his undoubted ability except to those who knew him well. The Navy at the time owed much to his influence and to his untiring application. He was made an O.B.E. at the end of the First World War.

He joined The Institution as an Associate in 1898 and was elected an Associate Member in 1902 and a Member in 1909. In 1903 he wrote, in conjunction with E. Fawssett, an Institution paper on distribution losses.

W. M. C.

ASHTON BURTON COOPER

Ashton Burton Cooper, B.Sc., who died on the 15th September, 1954, was born on the 31st December, 1883, at Belleville, Ontario, and came of United Loyalist stock. He was educated at Somerville Latin School, Massachusetts, and at Tufts College, where he studied electrical engineering. He took his B.Sc. degree in 1903, and soon afterwards began his practical training with the General Electric Co., Schenectady, where he specialized particularly in electrical testing and inspection. Leaving there in 1905, he joined the Pearson Engineering Corporation of New York City, with whom he assisted in the construction of the hydro-electric generating station at Lages in Brazil, the first station of its kind transmitting power to Rio de Janeiro. In 1909 he returned to the General Electric Co. as a commercial engineer, and was Manager of the Transformer Sales Department of the Canadian General Electric Co. from 1913 until 1922, when he accepted the post of General Manager of Ferranti in Canada. Mr. Cooper stayed with Ferranti until his death, becoming successively Vice-President and President of the Canadian Company, and also a Director of Ferranti Ltd. in Great Britain in 1947.

Mr. Cooper was a keen proponent of the Canadian Electrical Manufacturers' Association, and after helping in its formation, served as its first President in 1944–45; he was also Chairman of the Toronto branch of the Canadian Manufacturers' Association in 1928–29. Amongst his many other public activities, he served as Director of the Toronto Industrial Commission from its inception, and as President from 1951 to 1954. He was a Past-President of the Association of Professional Engineers of Ontario, and a Director of the Canadian National Exhibition. In 1927 Mr. Cooper became Vice-President of the American Institute of Electrical Engineers, holding office until 1929, and he was a Director of the Institute from 1930 until 1934.

He was very fond of golf, and was a keen Rotarian. Amongst the many social clubs of which he was a member are the Granite Club, the Canadian Club of New York, the Caledon Mountain Trout Club, and the Shawanaga Hunt Club. He is survived by his widow, a daughter and a son.

He joined The Institution as an Associate Member in 1929 and was elected a Member in 1945. V. Z. DE F.

EDWARD TOWNSEND HIPPISLEY

Edward Townsend Hippisley, M.A., who died on the 9th December, 1954, was born on the 20th July, 1893. He was educated at Westminster School, where he was a King's Scholar, and from there he went up to Trinity College, Cambridge, in 1912. He studied for the Mechanical Sciences Tripos, but his course was interrupted by the 1914–18 War. He joined the Royal Engineers and was commissioned in 1917; he served in Field Survey Battalions and did valuable work in connection with sound-ranging technique. He returned to Cambridge on demobilization in 1919 and took his B.A. degree the same year.

In 1920 he entered on a three-year post-graduate apprenticeship with the British Thomson-Houston Co. at Rugby, and early in 1923 he joined the staff of the Traction Department. He specialized at first in the design of traction motors, and spent some months during 1928 in the United States studying American work in this field.

From 1929 onwards Mr. Hippisley was responsible for heavy-traction contracts involving electric and Diesel-electric locomotives; and in June, 1936, he was appointed Manager of the Traction Department, a position he held with distinction until his death. He lectured and wrote widely on electric traction, gaining an Extra Premium for his Institution paper on the choice of electric traction-motor equipment. There were two papers by him included in the Convention on Electric Railway Traction organized by The Institution in 1950. He took his M.A. degree in 1935.

He was regarded with great respect and affection by all his staff, and, indeed, by all who knew him. He could be relied upon for wise counsel in any matter, and, added to his great technical ability, he had a wide knowledge of a variety of subjects including classics, history and law. He had a keen and wholesome sense of humour which helped him through many difficulties, including the ill health of later years. But despite illness, he carried on with his work nobly to the end and was in the office on the day he died. He will be remembered not only for his excellence as an engineer but for the uprightness of his character. The traction world mourns the loss of a man whose greatness physically was more than matched in mind and heart. He is survived by his widow.

He joined The Institution as an Associate Member in 1935 and was elected a Member in 1938. He served on the South Midland Centre Committee from 1944 to 1946.

He was also an Associate Member of The Institution of Civil Engineers and a Member of The Institution of Mechanical Engineers. J. H. C.

ROBERT VALENTINE MACRORY

Robert Valentine Macrory, M.B.E., who died suddenly on the 31st October, 1954, was born on the 14th February, 1878, at Ardmore Lodge, Limavady. He was the third son of the late Samuel Martin Macrory, J.P., a former High Sheriff of Londonderry. Mr. Macrory was educated at Cheltenham College and received his practical training with Siemens Bros. and Co., Woolwich, attending evening classes at Finsbury Technical and King's Colleges. He was appointed Engineer and Manager of the Londonderry electricity undertaking in 1898. At that time electricity supply was used for street lighting only—by means of arc lamps. A public supply was inaugurated in 1905 against much opposition (a number of citizens arguing that it could not pay). When Mr. Macrory became the Borough Electrical Engineer, he determined that the supply should be both economic and reliable. Over a period of about 50 years the breakdowns have in fact lasted for a total of about three hours, and a sum of slightly under £170 000 has been contributed by the electricity undertaking towards rate relief. To meet increased demand, Mr. Macrory put forward in 1941 a scheme for plant extension, to cost £79 000. This was turned down by the Northern Ireland Joint Electricity Committee and the Ministry of Commerce, who argued that a bulk supply from Belfast would be more economical. In 1946 Mr. Macrory arranged to have the two largest turbines modified to increase the maximum output of each by 1 000 kW, and this extra capacity enabled the undertaking to meet the demand on it. In 1949 the Ministry of Commerce gave permission for the extension refused in 1941, although the cost had now risen to £160 000. At the request of the Corporation Mr. Macrory undertook the work, which was completed in 1952.

On hearing of Mr. Macrory's death the Mayor of Londonderry said, "I was deeply grieved to hear of the passing of Mr. Macrory, both as a personal friend and as a member of the Corporation staff. For 56 years Mr. Macrory had been our City Electrical Engineer and no one has ever served his city more faithfully or with such charm and courtesy—characteristics which made him respected by all classes and creeds. . . . He loved his work and had but one ambition—to give Londonderry the best electrical service possible. I am sorry he did not live to realize his last great effort—to build a major power-house on plans at which he had been working for some time. His death leaves a gap in the life of our city which it will be very hard to fill—we shall miss him very much."

Mr. Macrory was a motoring pioneer, having about 1900 constructed a car, which he drove to Cork and back. He was also one of the first in Londonderry to own a phonograph, and he built a radio set which would receive almost all European stations except the local B.B.C. Station in Belfast, the predecessor of Lisnagarvey! He was a tactful man, who could usually get his way without upsetting his opponents.

In the New Year's Honours List for 1951 he was made an M.B.E. He is survived by his widow and a son.

He joined The Institution as an Associate in 1899 and was elected a Member in 1917. E. S. R.

PERCY MAW PINDER

Percy Maw Pinder, who died on the 27th September, 1954, was born on the 17th March, 1887, and educated at Harrogate College, King Edward VI Grammar School, Retford, and Leeds School of Technology. He received technical training with William Dawson and Sons, Otley, and then went as a pupil to Larne Electric Light Works. From 1909 to 1912 he was Charge Engineer with the Scottish Central Electric Power Co., Bonnybridge, and then held similar posts at both Altrincham and Wolverhampton, becoming in 1924 Boiler House Superintendent at Wolverhampton. He was released by Wolverhampton Corporation for service with the Royal Engineers in 1914–18. He was Station Superintendent at the Ironbridge generating station from the time of its construction in 1931 until his retirement in 1953. The installation of all the plant in this station was his responsibility.

Mr. Pinder will be particularly remembered by his colleagues as a sportsman and raconteur. He was Chairman of the Shropshire and Herefordshire Group of the Midlands Electricity Sports Club and a member of the Representative Council of that body. His experience proved most valuable, and his ready wit frequently enlivened the proceedings. He was keenly interested in cricket, particularly Yorkshire cricket, and took every opportunity in his leisure hours of visiting the various county grounds.

He was an excellent after-dinner speaker and was consequently extremely popular in the various societies of which he was a member, among which was the Wolverhampton Philatelic Society.

He joined The Institution as an Associate Member in 1919 and was elected a Member in 1936. He was also a Member of The Institution of Mechanical Engineers.

E. H. C.

MONOGRAPHS AND PAPERS
published separately this month

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A list of papers published in the March issue of Part B of the Proceedings appears under "Contents of the Current Issues of the Proceedings" on page 206, and the serial number of each paper and the month of publication of a digest in the Journal is included. Synopses of both Monographs and papers which will be published separately before the next issue of the Journal appear below, and unless otherwise stated, their date of publication is the same as this issue of the Journal. The monographs will be republished in Part C of the Proceedings, and the relevant Part for the republication of a paper is given after the serial number of the paper.

MONOGRAPHS

D. McDONNELL and W. R. PERKINS, B.Sc.

The Stability and Time Response to Fast-Operating Closed-Loop Pulsed Radar Circuits

MONOGRAPH No. 121 R

This paper deals with the stability and time responses of a sampling servo typical of a.g.c., a.f.c., range-measuring and overall-feedback circuits used in pulsed radar equipments in which the loop response time is not many times greater than the pulse repetition time. The case of a high-speed radar-controlled missile may be such a system.

Conditions under which Nyquist plots can be made are given. Expressions for the output both at and between the sampling times are obtained in terms of the input functions of the system. The operation of the systems in the presence of noise is not considered. A short list of transformations suitable for analysis is included.

A digest of the Monograph will be published in Part B of the *Proceedings*.

K. W. H. FOULDS, Ph.D., B.Sc.(Eng.)

Resonant-Cavity Measurements of the Relative Permittivity of a D.C. Discharge

MONOGRAPH No. 122 M

The relative permittivity of a gaseous discharge has been measured at 2 100 Mc/s, 2 500 Mc/s and 3 000 Mc/s, using an H_{011} resonant-cavity method. The preliminary experiments were carried out with a discharge in a mixture of argon (at a pressure of 2½ mm Hg) and mercury vapour. Later experiments employed a specially constructed low-pressure mercury-vapour tube. The relative permittivity of each discharge decreases from unity almost linearly for increases in the discharge current. In the low-pressure mercury-vapour discharge it has been observed that the Q-factor falls to a minimum at a particular value of discharge current that depends upon the resonant frequency of the cavity. It is suggested that this is due to an electron-resonance phenomenon.

The detailed theory of the method of measurement is given in an appendix.

A digest of the Monograph will be published in Part B of the *Proceedings*.

G. W. CARTER

A Note on the Surface Loss in a Laminated Pole-Face

MONOGRAPH No. 123

Linear electromagnetic theory is used in the paper to obtain a formula for the surface eddy-current loss in a laminated pole-face due to the flux-ripples induced by the opposing slotted armature, without any restrictive assumption about the thickness of the laminations. Earlier formulae are examined in the light of this more general theory, and a formula, derived by the author's father, the late Dr. F. W. Carter, is found to be a good approximation over a range of conditions frequently encountered in practice.

A digest of the Monograph will be published in Part A of the *Proceedings*.

PAPERS

G. H. METSON, M.C., Ph.D., M.Sc., B.Sc.(Eng.)

A Study of the Long-Term Emission Behaviour of an Oxide-Cathode Valve

PAPER No. 1790 R; PART B

The paper will be published on April 12th

The problem of maintaining satisfactory emission in an oxide-cathode valve over long periods of time is examined in broad rather than detailed manner. The approach is essentially experimental and starts from the basic assumption that the cathode will maintain its emission so long as it possesses a sufficiency of metallic barium in its oxide matrix. The general plan of the paper is to examine the several factors leading to loss and gain of barium metal within the cathode and then to attempt to estimate the conditions likely to result in a credit balance of barium over a long period of time. The tentative conclusion reached is that a cathode working under a current load in gas-free surroundings will continue to emit until the barium-oxide matrix is exhausted by electrolysis and evaporation.

C. CUTHBERT, B.Sc., and D. A. PICKEN

Timing the Operation of Control Systems associated with Rotating Equipment

PAPER NO. 1800 U; PART A

The problem of the exact time of operation of a contactor or braking device in a sequence is a common one, and by the application of the technique outlined in the paper, with simple apparatus, times can be measured to better than one-thousandth of a second. The application of this technique to a variety of methods of stopping two-roll rubber mills, as well as illustrating factors such as the time-constants of machinery, discloses some new mechanical problems about which very little is known, e.g. brake glide.

W. L. STEPHENSON, B.Sc.

Measurements of Junction Transistor Noise in the Frequency Range 7–50 kc/s

PAPER NO. 1811 R; PART B

The paper describes an investigation to determine the variation of junction-transistor noise with operating conditions (frequency, temperature, voltage and current) in the frequency range 7–50 kc/s. A detailed investigation involves a statistical analysis of a very large number of measurements, but since in this case it was required to determine only approximate laws, a small number of measurements were taken with the assumption of a large possible error. The noise voltages were measured using the superheterodyne principle to give constant bandwidth over the frequency range.

The analysis of the results is made using the principle of two equivalent noise generators in the input circuit: theoretical considerations link these with the minimum noise factor and optimum source resistance, which together determine the noise characteristics of the transistor.

W. HOLTTUM, M.Eng.

The Installation of Metal-Sheathed Cables on Spaced Supports

PAPER NO. 1814 U; PART A

The paper will be published on April 4th

The installation of cables above ground, mainly out of doors on hooks on posts, is a construction which has been extensively employed with lead-sheath power cables, and a material proportion of such cable has developed sheath fractures, shown by compound leakage, as a result of flexing in service caused by expansion and contraction with changes of temperature. While electrical failures due to this cause have been few, the desirability of eliminating or minimizing such sheath fractures, with the resultant loss of compound and eventual possibility of the entrance of moisture, needs no emphasis.

The behaviour of cables installed in this way is examined theoretically and by reference to service installations, and the conclusion is reached that the length between supports is the most important factor, normal practice having been to make this too short. A method is developed for determining for each cable what the minimum length should be, and other features of installation design are considered.

TECHNICAL PUBLICATIONS

BRITISH STANDARDS

The Secretary has been asked to draw attention to the following publications, copies of which can be obtained from the British Standards Institution, 2 Park Street, London, W.1.

HARD-DRAWN COPPER CONDUCTORS FOR OVERHEAD POWER TRANSMISSION PURPOSES (B.S. 125: 1954). 3s. (POST FREE).

In this revised Standard most of the provisions of the 1947 edition have been retained. The principal alterations are the adoption of the centigrade temperature scale, with a basic reference temperature of 20° C, instead of the Fahrenheit scale with a basic temperature of 60° F, and the introduction of revised values for constant-mass temperature coefficient of resistance and coefficient of linear expansion. In addition, the requirements of the tensile test have been altered.

ELECTRIC BOILING-PLATES FOR DOMESTIC PURPOSES (B.S. 744: 1954). 3s. 6D. (POST FREE).

The Standard specifies the construction and performance of sheathed-element and cast-iron-enclosed boiling-plates for domestic purposes, which are intended for operation on voltages not exceeding 250 volts. There is a comprehensive section on testing, which gives information on leakage current, electric strength, thermal efficiency, endurance tests, thermal shock tests, etc.

SIZES OF MANUFACTURERS' TRADE AND TECHNICAL LITERATURE (INCLUDING RECOMMENDATIONS FOR CONTENTS OF CATALOGUES) (B.S. 1311: 1955). 2s. 6D. (POST FREE).

The Standard has been prepared as a result of requests from a number of important trade associations, chiefly in the engineering and building industries, and no less than 38 organizations took an active part in the work. It is designed to overcome two main difficulties. First, when large plant is installed, the contractor's work is simplified if he can furnish full working instructions to his customer by assembling into one binder all the working instruction sheets issued by sub-contractors and suppliers of ancillary equipment. This is often not practicable unless all the literature is of the same size, and in any case a heterogeneous collection of sizes is untidy and hardly constitutes a good advertisement. Secondly, with catalogues, brochures and pamphlets similar considerations arise. The psychological aspect of this is particularly important for exports, because sizes of literature have been standardized in many countries for years. In addition, even if there is no question of grouping with other publications, a great variety of shapes and sizes can become a considerable nuisance to librarians.

Two sizes are provided and the choice between them will in practice be governed by requirements; both have the advantage that they can be cut from stock sizes of almost all the types of paper likely to be used.

LEAD-ACID TRACTION BATTERIES FOR BATTERY-ELECTRIC ROAD VEHICLES (B.S. 2550: 1954). 3s. (POST FREE).

This Standard does not cover batteries for industrial trucks (such as fork-lift types) for which a new Standard will be prepared in the near future. It deals with those types of lead-acid traction batteries which are used for the propulsion of battery-electric road vehicles of the four-wheeler, three-wheeler and pedestrian-controlled categories. It includes sections on design and construction, rating, designation, number of cells per battery, dimensions and layouts of standard units, and gives tests for capacity, variation of duration of discharge with temperature, life, etc. The illustrations include details of layouts for standard units, assembly, fittings and thimble sockets.

E.R.A. REPORTS

The Secretary has been asked to draw attention to the undermentioned Reports. Copies can be obtained from the British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

E.R.A. REPORT REF. A/T141. "BEHAVIOUR OF CELLULOSE ACETATE FILMS UNDER TROPICAL CONDITIONS." BY N. J. L. MEGSON AND V. E. YARSLEY. 27s. (POSTAGE 4D.).

Cellulose acetate films, of varying acetyl contents and containing a range of known plasticizers, were made up under standard conditions. The films were exposed to artificial and natural tropical conditions. The effect of such conditions was assessed by observations of mould growth formation, together with changes in visual appearance, electrical properties, mechanical properties and chemical composition. Comparative tests showed the significant difference between films made on a laboratory scale and those made industrially. The results indicated that changes in films were much greater after 12 weeks' natural exposure in West Africa than after 28 days in a "tropic" chamber, and no correlation between the two types of exposure was possible.

E.R.A. REPORT REF. G/T288. "AIR-BLAST CIRCUIT BREAKERS. A STATISTICAL STUDY OF THE VARIATION IN PERFORMANCE IN REPEAT TESTS OF A SINGLE BREAK EXPERIMENTAL UNIT WITH AXIAL BLAST." BY F. OLIVER MASON, B.SC.(ENG.). 10s. 6D. (POSTAGE 3D.).

This Report continues the study of variation in repeat tests experienced with an experimental air-blast breaker at the E.R.A. Laboratory, and describes the form of distribution obtained from a large number of tests at blast pressures below the working pressure for the circuit in question.

E.R.A. REPORT REF. G/T293. "THE EFFECT OF SERIES RESISTANCE ON THE CHARACTERISTICS OF CAPACITIVE SPARK DISCHARGES." BY H. G. RIDDLESTONE, B.SC.(ENG.). 10s. 6D. (POSTAGE 3D.).

The work described in E.R.A. Reports Ref. G/T253 and G/T278 has been continued. A new technique of measurement involving the use of a potential divider has enabled discharge characteristics and discharge energies to be measured over a range of circuit resistance up to 38 000 ohms and for discharges with durations as short as 8×10^{-8} sec. When the spark-gap is fitted with tungsten electrodes, the discharge energy decreases with increase in resistance over the whole range, but with steel electrodes the energy increases again for resistances above 11 000 ohms. For resistances between 200 ohms and 11 000 ohms the discharge energies are greater for tungsten electrodes. There is a slight knee in the discharge-energy/resistance curve at the value of resistance which corresponds to the minimum discharge duration.

E.R.A. REPORT REF. L/T311. "ALTITUDE CORRECTION FACTORS FOR SPARKOVER VOLTAGES OF INSULATORS AND ROD GAPS." BY A. MORRIS THOMAS, B.SC. 10s. 6D. (POSTAGE 3D.).

Altitude correction factors for sparkover voltages of insulators and rod gaps involve the variation of the density of the atmosphere with altitude and sparkover voltage as a function of air density. The atmospheric density variation is calculated for the I.C.A.O. Standard Atmosphere. It is shown that, in accordance with Paschen's law, sparkover voltage is not, in general, directly proportional to air density, and the air-density correction depends to some extent on a linear dimension of the system. For practical purposes, however, a 0·75 power law provides a basis for the estimation of altitude correction factors.

Recently it has been proposed that the standard altitude correction factor should be such that the normal standard test voltages at sea level should be increased by 3·5%, for each 1 000 ft in excess of 3 300 ft with insulators and air clearance designed for service at high altitudes. It is suggested that this proposal needs reconsideration as it yields test voltages which are too high by several per cent.

E.R.A. REPORT REF. L/T313. "NOMOGRAMS AND LINE CHARTS FOR HUMIDITY CORRECTION FACTORS APPLICABLE TO FLASHOVER TESTS ON INSULATORS." BY A. MORRIS THOMAS, B.SC. 6s. (POSTAGE 3D.).

The flashover voltages of insulators, e.g. outdoor bushings and overhead-line insulator strings, in air are, other things being equal, dependent on the absolute humidity of the air, i.e. the quantity of water vapour present in unit volume of the air. An absolute humidity of 11 g of water vapour per cubic metre of the moist air has been adopted as the standard condition by the I.E.C., B.S.I. and other standardizing organizations.

To convert a measured air-flashover voltage to the value which would be obtained with the standard condition, it is necessary to multiply it by a correction factor, when the prevailing absolute humidity differs from the standard value. This correction for humidity is applied in addition to that required for air density. Hitherto humidity correction factors incorporated in specifications of the B.S.I. and the I.E.C. have been given in the form of curves in which the factors are presented as functions of the absolute humidity. It is simplest and customary to determine absolute humidity indirectly, by measurement of relative humidity and temperature, but this involves reference to hygrometric tables, interpolation and computation. This labour is entirely avoided if the nomograms and line charts here presented are used.

E.R.A. REPORT REF. S/T61. "BLOWING OF FUSES IN DISTRIBUTION SYSTEMS DURING THUNDERSTORMS." BY J. L. MILLER, PH.D., B.SC. 6s. (POSTAGE 3D.).

The blowing of fuses under lightning conditions is known to constitute a major source of trouble in distribution systems. The present Report summarizes the published information available and examines in some detail the various probable causes to which fuse blowing may be due.

some recent BOOKS

W. E. FORSYTHE (*Editor*)
SMITHSONIAN PHYSICAL TABLES
WASHINGTON: THE SMITHSONIAN INSTITUTION. 9TH EDITION. 833 PP. $10.

This new edition of the Smithsonian Physical Tables is probably the most comprehensive single-volume set of tables of physical constants in existence; as such it can be commended to engineers who from time to time require scientific data outside the scope of engineering handbooks. Its range is enormous, covering as it does the basic concepts of physics, chemistry and astronomy in considerable detail. New data in atomic physics form a notable contribution to this edition. In its detail the book almost approaches the International Critical Tables, and to have achieved this result in a single volume that is lighter in weight and no bigger than the average textbook is quite a feat in book production.

The edition was edited by W. E. Forsythe, who was formerly a physicist with the General Electric Company of America, and it is therefore not surprising to find that data of technical as well as of purely scientific interest are well represented in the tables; e.g. magnetic data for modern alloys and dielectric data for modern insulants, as well as the atomic and molecular constants associated with the theory of such materials. Members of the staff of the National Bureau of Standards and of other American organizations of similar standing have made contributions in various specialized fields, and have thereby ensured that up-to-date information on most branches of physical science is included and that the work reaches a high standard.

Judged by this high standard, however, the book does seem in places a little weak in one respect, namely the degree of co-ordination among the various tables bearing on one subject. New tables of values seem to have been inserted quite regardless of inconsistencies between them and other tables in the book. Thus, where the reader expects to find one comprehensive table for a particular property, he may find several tables from different sources with little attempt to show the relation between them. A clearer presentation of the main divisions and a critical overhaul of related tables in each section would greatly increase the value of the work. For example, Table 448 gives dielectric constants at radio frequencies and Table 452 gives power factors; Table 454 gives both dielectric constants and power factors and is separated from the earlier tables by three pages on antenna arrays. Again, it is odd to find in such a work a good up-to-date theoretical treatment of the electrical units, but only a very inadequate statement of the actual e.m.f. of a standard cell, and, incidentally, almost no data concerning hydrogen-ion concentration. However, in spite of such imperfections in its details, the book will be of great service in making so much of the data of the physical sciences so readily accessible.

F. V. HUNT
ELECTROACOUSTICS
CAMBRIDGE, MASSACHUSETTS: HARVARD UNIVERSITY PRESS, AND NEW YORK: JOHN WILEY. 269 PP. $6.

The sub-title of the book is "The Analysis of Transduction, and its Historical Background." The historical introduction (Chapter 1; 91 pages) is itself the product of extensive research into the literature of the subject. We have the author's assurance that it is based on the cited primary sources and that every bibliographical reference (of which there are many) has been verified at first hand. The result is a masterpiece of condensation, not merely a catalogue of facts but an essay having literary merit, most readable and of absorbing interest to any student of electro-acoustics. Full use has been made of patent references, which undoubtedly enhance the authoritative quality of the work, though they tend to make the book lay most emphasis on that which is patentable (e.g. transducers).

Chapters 2, 3 and 4 discuss (in general terms) electromechanical coupling in electro-acoustic transducers. They develop the theme by viewing the transducer from its electrical terminals and observing the effects of the motion of the coupled mechanical system on the electrical impedance and admittance (a method started by Kennelly and Pierce in 1912). The theory which results becomes substantially identical with the theory of electric networks.

The three remaining chapters illustrate this method of analysis with reference to moving-conductor, electrostatic and moving-armature systems, respectively. Each of these chapters suffers (as does the book itself) from far too wide a title. Thus the chapter on "Moving-Conductor Transducer Systems" is almost wholely restricted to the direct-radiator moving-coil type of loudspeaker and to its performance at low frequencies only. Even in this limited range the acoustical loading is taken for granted and the vitally important question of what is the proper criterion of performance of a loudspeaker is not faced. Surely it is unwise to rely only on electrical impedance measurements to decide, for example, the optimum adjustment of a bass-reflex enclosure of a loudspeaker.

That the book deals only with a very limited aspect of electro-acoustics should be recognized; nevertheless it undoubtedly contributes to our knowledge of electromechanical coupling in transducers in a manner that is academically stimulating and practically useful in its specialized field. It is of interest to note that the core of the matter is based on researches at the Harvard Underwater Sound Laboratory. The manner of presentation is uniformly excellent throughout the book, even while the author is embarked upon his "algebraic wars," which he controls with economy and effect.

R. G. WILLIAMS
LIGHTING FOR COLOR AND FORM
PITMAN. 356 PP. £2 5S.

Although the author was, for many years, well known to lighting engineers in Britain as a skilful exponent of coloured lighting, and although his qualifications, as stated on the title page, are those of the (British) Illuminating Engineering Society, his book reflects, probably inevitably, the American outlook, and almost all the illustrations are of American origin; many, in fact, are reproduced from the (American) Illuminating Engineering Society Handbook. This is not an adverse criticism but it is an important fact which the reader should keep carefully in mind, especially if he is not thoroughly familiar with British practice in the field covered.

The first part of the book deals with the fundamentals of

vision, lighting, colour mixture, colour specification and colour rendering. This is a good introduction to the subjects covered in the remainder of the book, at any rate so far as the general reader is concerned; it is not everywhere a safe guide for the student.

Part 2 has three chapters on the production of coloured light and its control, both in intensity and in distribution. Here the reader is introduced to a world of specialized equipment, much of it known by some name which is quite unfamiliar to all except those concerned with theatrical or studio production. What, for instance, is a "scoop" or a "revolving borderlight"? The descriptions of the many different types of dimmers, too, will come as a revelation to most electrical engineers.

Part 3, on psychological and aesthetic factors, will be to many readers the least satisfactory portion of the book, just as the second part will be found the most valuable and informative.

The last part deals with the technique, or rather techniques, of using coloured light for several different purposes, which are grouped, for convenience, in seven chapters. Display lighting has much in common with stage lighting, but there are also many differences, and the author wisely does not attempt to deal with the two subjects together. In one chapter he treats of lighting, and particularly coloured lighting, as an element in architectural design, and here will be found a description of the author's *tour de force*, the glass-fronted lobby of a company headquarters in New York, with a total connected lamp load of 288 kW and provision for producing "500 basic hues and tints of light combined in spectacular patterns involving unlimited static or mobile colour effects." Other chapters deal with studio lighting (photographic, cinema and television), sign lighting, special "trick" lighting and light for photochemical reproduction processes.

The book can be thoroughly recommended as a most interesting and useful guide to those who, generally familiar with the use of light for ordinary purposes, wish to make an excursion into the less familiar world of coloured light. The standard of production is high and there is a good index.

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* *Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members.*

NATIONAL BUREAU OF STANDARDS, UNITED STATES DEPARTMENT OF COMMERCE

Contributions to the Solution of Systems of Linear Equations and the Determination of Eigenvalues, edited by O. Taussky. (Applied Mathematics Series 39)

4to. pp. 139. Washington: U.S. Government Printing Office, 1954. $2

Formulas for Computing Capacitance and Inductance, by C. Snow (Circular 544)

4to. pp. 69. Washington: U.S. Government Printing Office, 1954. 40 cents

Miniature Intermediate-Frequency Amplifiers, by R. K.-F. Scal (Circular 548)

4to. pp. 46. Washington: U.S. Government Printing Office 1954. 40 cents

Tables of the Error Function and its Derivative (Applied Mathematics Series 41)

4to. pp. 313. Washington: U.S. Government Printing Office, 1954. $3.25

Table of the Gamma Function for Complex Arguments (Applied Mathematics Series 34)

4to. pp. 121. Washington: U.S. Government Printing Office, 1954. $2

Tables of Sine and Cosine Integrals for Arguments from 10 to 100 (Applied Mathematics Series 32)

4to. pp. 202. Washington: U.S. Government Printing Office, 1954. $2.25

NATIONAL PHYSICAL LABORATORY

Audio Frequency Power Measurements (Notes on Applied Science No. 8)

8vo. pp. 16. London: H.M.S.O., 1954. 1*s*.

LIBRARY ACCESSIONS

Automatic Digital Computation: Proceedings of a symposium held at the National Physical Laboratory, March, 1953

4to. pp. 296 London: H.M.S.O., 1954. 21*s*. *

Gauge Making and Measuring (Notes on Applied Science No. 5)

8vo. pp. 79. London: H.M.S.O., 1954. 3*s*.

NEW YORK UNIVERSITY, INSTITUTE OF MATHEMATICAL SCIENCES, DIVISION OF ELECTROMAGNETIC RESEARCH

Propagation in Semi-Infinite Waveguides. Six papers by L. A. Vajnshtejn, translated from the Russian by J. Shmoys

Research Report No. EM-63. New York: New York University, 1954

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION

Heavy Equipment for Power Stations, 7th Survey. Deliveries and Orders on the 1st April, 1954

4to. pp. 51. Paris: O.E.E.C., 1954

The Price of Electricity and its Relation to Investment in the Electricity Supply Industry

4to. pp. 103. Paris: O.E.E.C., 1954

The Organisation of Applied Research in Europe, the United States and Canada

3 vols. 4to.
Vol. 1: A Comparative Study. pp. 76 Vol. 2: Applied Research in Europe. pp. 181 Vol. 3: Applied Research in the United States and Canada. pp. 125 (Report of Technical Assistance Missions No. 81, 82, 83). Paris: O.E.E.C., 1954.

TELEVISION SOCIETY

A Bibliography of Colour Television

4to. pp. 17. London: Television Society, 1954.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH FEBRUARY, 1955

	No. of Contributors	£	s.	d.
£1 000 and over	6	6 000	0	0
£100 to <£1 000	29	6 386	3	0
£5 to <£100	734	8 157	14	4
£2 to <£5	1 771	4 944	18	7
Under £2	16 789	8 998	18	9
		£34 487	14	8

'CHARTERED ELECTRICAL ENGINEER'

The Council believe that a wider use of the designation "Chartered Electrical Engineer" would help towards a fuller understanding on the part of the public of the professional character of Corporate Members of The Institution. All Corporate Members are encouraged to use this title in the manner prescribed in the Bye-Laws wherever appropriate, and in particular on individual letter-headings, reports and publications.

Members are reminded that some notes on the use of this designation are given in Section 3.2 of the booklet "The Institution: Its Objects and Organization."

GIFTS TO THE INSTITUTION

The Council have expressed their cordial thanks to the donors of the following gifts to The Institution:

From Mr. A. G. Long, Associate

A torsion galvanometer of compact design, with hair-spring control, of early French manufacture.

From Mr. C. W. Speirs, J.P., Member

Four letters written to Mr. Speirs between 1905 and 1909, three being from Sir Charles Parsons and one from Professor W. E. Ayrton.

From Mr. G. Mather, B.Sc.Tech., Member

Two photographs of the grave of Sir Ambrose Fleming, and five photographs relating to an early Drysdale a.c. potentiometer now in the Science Museum.

From E.M.I. Research Laboratories Ltd.

A television camera tube from the original 405-line equipment at Alexandra Palace.

SCHOLARSHIPS

The Council invite applications for the following scholarships which are offered for award this year:

RESEARCH SCHOLARSHIPS

Ferranti	Value £500 p.a. for two years.
Oliver Lodge	Value £420 for one year; may be extended.
I.M.E.A.	Value £420 for one year; may be extended.
Swan Memorial	Value £120 for one year.
C. P. Sparks Fund	Value £100 for one year.

GRADUATE SCHOLARSHIP

Duddell	Value £400 for one year.

STUDENT SCHOLARSHIPS

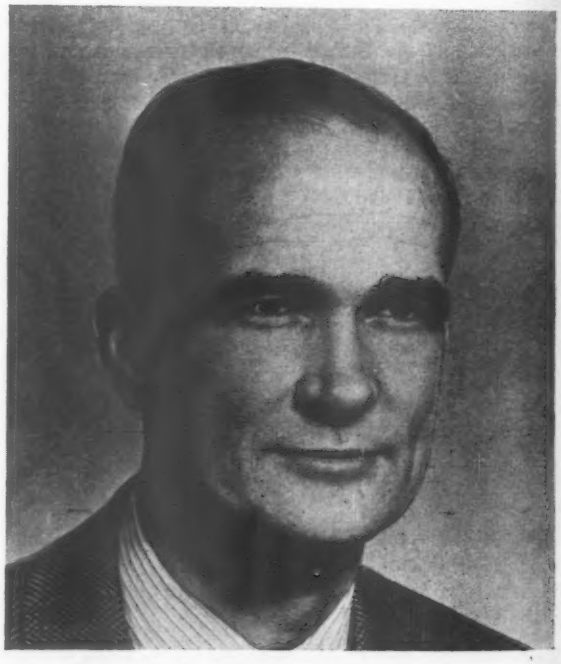
**Duddell*	Value £200 p.a. for three years.
Arthur Fleming	Value £120 p.a. for four years.
Salomons	Value £60 for one year.
David Hughes	Value £60 for one year.
Paul	Value £75 p.a. for a period not exceeding four years.
Thorrowgood	Value £25 for one year.

The Arthur Fleming Scholarship is a new award which has been established by the Council for a student wishing to follow a works-based sandwich diploma course in electrical engineering.

The closing dates for the receipt of applications are the 2nd May, 1955, for Student Scholarships, and the 1st June, 1955, for Graduate and Research Scholarships. Further particulars of the above awards and nomination forms may be obtained on application to the Secretary.

THE KELVIN LECTURE

The Forty-Sixth Kelvin Lecture, on "Transistor Physics," will be given by W. Shockley, B.Sc., Ph.D., on the 21st April, 1955.



Dr. Shockley, a photograph of whom appears above, was born in 1910. He studied at the California Institute of Technology and was appointed a Fellow of the Massachusetts Institute of Technology in 1932. He joined the Bell Telephone Laboratories in 1936, and returned to that organization in 1945 after three years of war research and consultancy for the

* The Duddell Scholarship will not be available as a Student Scholarship if it is awarded as a Graduate Scholarship.

United States Government. He was appointed Director of Transistor Physics Research of the Bell Telephone Laboratories in 1953, but he is at present on leave of absence from this appointment to the Department of Defense, Washington.

Dr. Shockley directed the group which developed the transistor, of which he is also one of the joint inventors. During the past six years he has made many contributions to solid-state physics, particularly in connection with the transistor. In addition to solid-state physics and semiconductors, his work has included valve and electron-multiplier design, radar development and research on magnetism.

Among the honours that have been awarded to Dr. Shockley are the Medal for Merit of the United States War Department, the Morris Liebmann Memorial Prize of the Institute of Radio Engineers, the Oliver E. Buckley Solid-State Physics Prize of the American Physical Society and the Comstock Prize of the National Academy of Sciences.

The Institution is indeed fortunate that this distinguished American scientist, who is a renowned expert on a subject of great moment, has consented to deliver the 1955 Kelvin Lecture.

Members wishing to bring visitors to the Lecture are asked to note that they are restricted to one per member and that tickets for their admission must be obtained from the Secretary.

THE JAMES WATT INTERNATIONAL MEDAL

The Council of The Institution of Mechanical Engineers have awarded the 1955 James Watt International Medal to Dr. Igor Ivan Sikorsky, of the United States, in recognition of his life's work in applying science to the progress of mechanical engineering, through pioneering development of multi-engined, amphibian, and, particularly, helicopter aircraft.

The James Watt International Medal was founded to commemorate the bi-centenary of the birth of James Watt, which took place on the 19th January, 1736. The award, which takes the form of a gold medal, is made every two years to an outstanding mechanical engineer, who may be of any nationality; it is the highest honour bestowed by The Institution of Mechanical Engineers.

MEASUREMENTS SECTION COMMITTEE

The Measurements Section Committee have received with regret the resignation from the Committee of P. Vigoureux, D.Sc.(Eng.), Associate Member, on his taking up an appointment in Washington.

Under the provisions of Regulation 11(*b*) the Committee have appointed Mr. J. Bell, M.Sc., Member, to fill the vacancy.

SUPPLY SECTION

VISIT ON THE 30TH APRIL, 1955

The visit to the Lime Grove Television Studios and the White City Television Centre to be made on the 30th April, 1955, was over-subscribed within two days of the circular being sent out, and the Committee accordingly decided to hold a ballot of all the applications received by February 22nd. This duly took place and the results have been notified to all applicants.

We regret that no further applications can be accepted.

DISCUSSIONS AT MEETINGS

The Council desire it to be understood that contributions to the discussions at meetings should not be read from manuscript, since they consider that this form of presentation is contrary to the true spirit of a discussion.

ELECTIONS AND TRANSFERS

Particulars of 223 elections and 94 transfers approved by the Council will be found on page 204.

TRANSACTIONS OF THE INSTITUTE OF RADIO ENGINEERS

Members who subscribe to the *Transactions of the Institute of Radio Engineers*, which are issued under the headings of the various Professional Groups of the Institute, will be interested to learn that the Executive Committee of the Institute have kindly agreed to accept subscriptions for the *Transactions* at the specially reduced rate of $8.50 (£3 1*s.*) per annum for a single Professional Group. All subscriptions and inquiries should be addressed to the Secretary of The Institution and *not* to The Institute of Radio Engineers. A subscription covers the 12 months beginning in July of any year and can be made retrospective only if back copies of the required *Transactions* are still available.

The following is a complete list of the 21 Professional Groups of the Institute of Radio Engineers for which *Transactions* are published:

Aeronautical and Navigational Electronics
Antennas and Propagation
Audio
Broadcast and Television Receivers
Broadcast Transmission Systems
Circuit Theory
Communications Systems
Component Parts
Electron Devices
Electronic Computers
Engineering Management
Industrial Electronics
Information Theory
Instrumentation
Medical Electronics
Microwave Theory and Techniques
Nuclear Science
Quality Control
Radio Telemetry and Remote Control
Ultrasonics Engineering
Vehicular Communications

HARVARD UNIVERSITY GRADUATE SCHOOL OF BUSINESS ADMINISTRATION

Two Fellowships at the Harvard University Graduate School of Business Administration which last for two years from September, 1955, are now available. Each is worth approximately £2 000, and in addition a successful candidate for a Fellowship, or his employer, must provide £1 000. Candidates must be British, and preferably possess a university degree; they must have had several years' experience in industry. Details are available from the British Institute of Management, Management House, 8 Hill Street, London, W.1.

FIFTH WORLD POWER CONFERENCE

VIENNA, 17TH–23RD JUNE, 1956

The final text of the Technical Programme of the Fifth Plenary World Power Conference, to be held at Vienna from the 17th to 23rd June, 1956, is now available. Members living in the United Kingdom can obtain copies from The Secretary, British National Committee, World Power Conference, 201–2 Grand Buildings, Trafalgar Square, London, W.C.2;

oversea members are asked to apply to the Secretary of the relevant National Committee or direct to Österreichisches Nationalkomitee der Weltkraftkonferenz, Vienna 1, Schwarzenbergplatz 1, Austria. A British Papers Committee has been set up, under the chairmanship of the President of The Institution, to make arrangements for the preparation of British papers within the scope of the Fifth World Power Conference. Communications intended for this Committee should be sent to the Secretary of the British National Committee at the address given above.

CAMBRIDGE SUMMER SCHOOL IN AUTOMATIC COMPUTING, 1955

A Summer School in programme design for automatic digital computing machines will be held in the University Mathematical Laboratory at Cambridge from the 12th to 23rd September, 1955. It will be along the same lines as those held previously, and will give a basic training in the mathematical use of machines, dealing with the processes employed and their embodiment in programmes which specify detailed operation. Lectures and practical classes will be held in the design of programmes for the EDSAC, the machine which has been built in the Laboratory.

A detailed syllabus and form of application for admission may be obtained from Mr. G. F. Hickson, Secretary of the Board of Extra-Mural Studies, Stuart House, Cambridge, to whom the completed application form should be returned not later than the 15th June, 1955.

SUMMER SCHOOL IN SYSTEM PROTECTION

A Summer School in System Protection will be held at the Borough Polytechnic, London, from the 18th to 28th July, 1955. The School will mainly comprise laboratory tests on the following aspects of protection:

System performance under fault conditions.
Protective systems and transductors.
Relays.
Protective systems, including mono- and duo-bias, carrier-current, and phase-comparison systems.
Arc suppression.
The recurrent-surge oscillograph for examination of surge-voltage distribution in a transformer winding.

The fee for the course, including accommodation, board and tuition, is 15 guineas. Further details and application forms can be obtained from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

RESIDENTIAL COURSE ON MAGNETIC AMPLIFIERS

The Somerset Education Committee, in collaboration with the Regional Committee for Further Education for the South-West, are holding from the 25th to 29th April, 1955, a short residential course on Magnetic Amplifiers, which will be directed by E. Frost-Smith, B.A., Ph.D. It will be held at the Committee's college for adult education, Dillington House, Ilminster, which is a beautiful country house situated in formal gardens with an adjoining arboretum. The course is designed for students from industry and colleges, with Graduate or Higher National Certificate qualifications, and is not limited to those living in South-West England; it consists of lectures by Dr. Frost-Smith, followed by discussions. It is intended to give an introduction to the theory and practice of magnetic amplification to those not already specializing in this subject. The majority of bedrooms in Dillington House are large, with five or six beds, but there are a few bedrooms with two beds only. The food provided is said to be very good.

The fee for the course, including tuition, accommodation and board, is 6 guineas. The programme of the course and full particulars can be obtained from the Warden, Dillington House, Ilminster, Somerset.

MANAGERS IN INDUSTRY

A RESIDENTIAL COURSE AT MADINGLEY HALL, CAMBRIDGE

The third residential course for Managers in Industry will take place at Madingley Hall, Cambridge, from the 27th June to the 22nd July, 1955. The course, which is intended primarily for industrial managers under 40 years old, is designed to throw light on the role of the manager and on his responsibilities in present-day society. The field of the course is wide, but much of the work will hinge on the following five topics:

1. The nature of managerial authority and responsibility.
2. The relationship between the Government and private industry.
3. The human problems of industrial change.
4. The role of the trade unions to-day.
5. Management and the change in structure of national economy.

Special attention will be given to problems arising from external or internal changes affecting an industrial organization.

Those taking the course will work in small groups under different chairmen and secretaries for discussion of each topic. Visiting lecturers from industry and Cambridge University will address the course, and there will be time allocated for the reading of appropriate books. The discussions culminate in written reports, which will in turn be discussed by all those on the course.

Madingley Hall is a delightful house, some of it dating from the 16th century, in a pleasant position about four miles west of Cambridge. Members of the course will be accommodated in it in single bed-sitting rooms. There are many facilities for sport.

The fee for the course, including tuition, accommodation, board and gratuities, is £100. Full particulars and application forms can be obtained from the Secretary, Course for Managers in Industry, Stuart House, Cambridge, and the completed forms should reach him not later than the 4th April, 1955.

CORRECTIONS

PROCEEDINGS, PART II, DECEMBER, 1954

The following amendment should be made to the paper entitled "Safety in the Use of Portable and Transportable Electrical Equipment in Industry," by J. W. Bunting, to avoid ambiguity: in Section 4.4, page 586, four lines from the foot of the page, for "The neutral of the supply should . . .", read "The neutral or star-point of the supply transformer should . . .".

JOURNAL, JANUARY, 1955

The following corrections apply to the article entitled "A Transatlantic Telephone Cable": on page 25, left column, lines 13 and 14, for "Brunel's ill-fated dream ship, the *Great Eastern* . . .", read "The *Agamemnon* and *Niagara* . . ."; on the same page, in Fig. 1, the radio link shown from Terrenceville to Sydney Mines should be a cable link.

THE JOURNAL REFERENCE SECTION *(pages 203-208)*

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Elections and Transfers

The following elections and transfers approved by the Council are effective from the 3rd February, 1955.

ELECTIONS

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ASHWORTH, Stanley
BALKWILL, Bertram John.
BENNETT, Donald John, B.E.
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BLACKMORE, James Henry.
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CARR, Michael George.
CARTER, Leslie Eugene.
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CLARK, George Wilson.
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COOKE, Dennis Howard.
COX, Leslie Moncrieff.
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CROWTHERS, Thomas Alan, B.Sc.
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GHOSE, Arabinda.
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HALL, George Albert.
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HORLICK, Robert James, B.A.
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HUGHES, Kenneth Hamshaw.
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KAPOOR, Joginder Paul, B.A.
KENNEDY, Peter Frost, B.Sc.
KHATTAK, Musanif Shah, B.Sc.
KNIGHT, Robert William, M.Sc.
LAMONT, John.
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LORENZO, Edward.
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MAUGHAN, Alan.
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WILLIAMS, Thomas Kenneth.
WOOD, Henry Spilman.

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MALIK, Aftab Ahmed Khan.
MANGAPATIRAO, Avasarala.
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MASON, Gerald Alfred.
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YOUNG, Ian Gerald, B.Sc.

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Student to Graduate

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AGBETTOR, Emmanuel Ofoe, B.Sc. (Eng.).
ASH, John Wesley.
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CRAWLEY, John Phillips, B.Sc.(Eng.).
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DEB, Benoy Krishna.
DICK, George Callan.
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FINKELSTEIN, Ludwik, B.Sc.
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GHOSH, Dilip Kumar, B.Sc.(Eng.).
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GRAY, Cyril John Alan.
HARDWICK, Ivan Roy.
HARDY, Michael James.
HARRISON, Philip George.
HASSABIS, Stavros Costi.
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HENDERSON, Stanley Carstairs.
HICKS, Stuart Hooper.
HOLMES, Cyril.
JANARDHAN, Narienkadu Mohanarunga, B.E.
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JONES, Ernest Robert.
KAYE, Gerald.
KELKAR, Kishor Shridhar.
LEDDRA, Herbert.
LEONARD, John Herbert.
LINDSAY, James Forrest, B.Sc.
LOJ, Jerzy.
LORD, Norman Greenwood.
McAREAVEY, Frank.
McDOWELL, James.
McKELVIE, Alastair Hugh.
McKEON, Alexander, B.Sc.(Eng.).
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MARSH, Roy David, B.Sc.(Eng.).
MAVIN, Thomas Jackson.
MURRAY, George William.
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PRENTICE, James William.
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Forthcoming Events *at savoy place*

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E	EDUCATION DISCUSSION CIRCLE	**O**	ORDINARY MEETING
Ex	EXTRA MEETING	**R**	RADIO SECTION
I	INFORMAL MEETING	**S**	SUPPLY SECTION
M	MEASUREMENTS SECTION	**U**	UTILIZATION SECTION

After each paper that has now been published is added the month that its synopsis appeared in the *Journal*.

1955

MARCH

21 *Monday* — R. O. JENKINS, PH.D., will open a discussion on "Materials for Valves"† — **R**

22 *Tuesday* — T. SIKLOS, DIPL.ING., will open a discussion on "High-Voltage Equipment in Colleges"* (at 6 p.m., tea at 5.30 p.m.) — **E**

22 *Tuesday* — Section Dinner-Dance (at the Café Royal at 7 for 7.30 p.m.) — **S**

23 *Wednesday* — J. CHRISTIE, H. LEYBURN, B.SC.(ENG.), *and* J. F. BIRD, M.C., T.D., B.SC. — **S**
"Proving the Performance of Circuit-Breakers, with particular reference to those of Large Breaking Capacity" (Paper No. 1707)‖ *Synopsis:* August, 1954

J. CHRISTIE, H. LEYBURN, B.SC.(ENG.), *and* R. W. FENN, M.ENG.
"A New Testing Station for High-Power Circuit-Breakers" (Paper No. 1736)‖ *Synopsis:* December, 1954

30 *Wednesday* — Radio and Measurements Sections Dinner-Dance (at the Café Royal at 7 for 7.30 p.m.) — **R and M**

31 *Thursday* — E. W. GOLDING, M.SC.TECH. — **O**
"Electrical Energy from the Wind" (Paper No. 1727)‖ *Synopsis:* December, 1954

APRIL

5 *Tuesday* — D. M. MACKAY, B.SC., PH.D. — **R and M**
"High-Speed Electronic-Analogue Computing Techniques" (Paper No. 1738)‖ *Synopsis:* October, 1954

14 *Thursday* — W. HOLTTUM, M.ENG. — **U**
"The Installation of Metal-Sheathed Cables on Spaced Supports" (Paper No. 1814)§ *Synopsis:* See page 196

18 *Monday* — H. W. SWANN, O.B.E., will open a discussion on "Domestic Circuits and Protection Devices"* — **I**

19 *Tuesday* — R. DAVIS, M.SC., will open a discussion on "The Measurement of Impulse Voltages and Currents with special reference to the Testing of Surge Diverters"† — **M**

20 *Wednesday* — G. H. METSON, M.C., PH.D., M.SC., B.SC.(ENG.) — **R**
"A Study of the Long-Term Emission Behaviour of an Oxide-Cathode Valve" (Paper No. 1790)§
Synopsis: See page 195

21 *Thursday* — W. SHOCKLEY, B.SC., PH.D. — **O**
The Forty-Sixth Kelvin Lecture on "Transistor Physics"*

22 *Friday* — K. R. STURLEY, PH.D., B.SC., will open a discussion on "Technical Training in North-West Germany"* (at 6 p.m., tea at 5.30 p.m.) — **E**

27 *Wednesday* — G. F. PEIRSON, A. H. POLLARD, B.SC., *and* N. CARE — **S**
"Automatic Circuit Reclosers" (Paper No. 1717)‖ *Synopsis:* December, 1954

28 *Thursday* — H. I. ANDREWS, M.SC., PH.D. — **Ex**
"The Adhesion of Electric Locomotives" (Paper No. 1797)§

MAY

2 *Monday* — H. V. HIGGITT — **R**
Informal Lecture on "A Simple Introduction to Telegraph Codes"‡

* No advance information will be available.
† An abstract of the introduction will be available in advance.
‡ A synopsis will be available in advance.
§ This paper will be published not later than 10 days before the date of reading.
‖ This paper has now been published (see page 195).

MAY

3	*Tuesday*	PROFESSOR W. V. MAYNEORD, D.SC. Lecture on "Medical Uses of Radioactive Isotopes"*	M
4	*Wednesday*	SIR HAROLD HARTLEY, K.C.V.O., C.B.E., F.R.S. First Graham Clark Lecture on "The Engineers' Contribution to the Conservation of Natural Resources"* (Joint Meeting with The Institution of Civil Engineers, and The Institution of Mechanical Engineers at The Institution of Civil Engineers, Great George Street, S.W.1)	
5	*Thursday*	W. GREY WALTER, M.A., SC.D. Lecture on "The Electrical Activity of the Brain"*	U
11	*Wednesday*	Group of papers on "Transistors and other Semi-Conductor Devices," including:	R
		W. L. STEPHENSON, B.SC. "Measurements of Junction Transistor Noise in the Frequency Range 7–50kc/s" (Paper No. 1811)‖ *Synopsis:* March, 1955	
		G. R. NICOLL, B.SC. "Noise in Silicon Microwave Diodes" (Paper No. 1671) (Published in the *Proceedings*, Part III, September, 1954)	
12	*Thursday*	W. J. OOSTERKAMP, M.A., PH.D., *and* G. M. ARDRAN, M.D., will open a discussion on "Image Intensification in Radiology"†	Ex
17	*Tuesday*	Questions Night* (At 6 p.m., tea 5.30 p.m.)	E
18	*Wednesday*	D. B. IRVING, B.SC. "The Supply of Electricity in the London Area" (Paper No. 1748)‖ *Synopsis:* November, 1954	S
19	*Thursday*	Annual General Meeting (Corporate Members and Associates only) *followed by*	
		THE RT. HON. LORD CITRINE, P.C., K.B.E. Lecture on "Human Relations in Industry"* (At approximately 6.30 p.m. Open to all members)	
21	*Saturday*	Utilization Section Summer Visit to the Atomic Energy Research Establishment, Harwell	U

* No advance information will be available.
† An abstract of the introduction will be available in advance.
‖ This paper has now been published (see page 195).

Contents of the current issues of the Proceedings

DATE OF JOURNAL DIGEST OR SPECIAL ARTICLE	PART A. POWER ENGINEERING (FEBRUARY, 1955)
	J. ECCLES, C.B.E., B.SC. **Inaugural Address**
January 1955	J. I. BERNARD, B.SC.TECH. **Utilization Section: Chairman's Address**
January 1955	J. D. PEATTIE, B.SC. **Supply Section: Chairman's Address**
January 1955	M. WHITEHEAD **Measurements Section: Chairman's Address**
	Discussion on **Electrical Discharges in Air-Gaps facing Solid Insulation in High-Voltage Equipment** before the South Midland Centre
	Local Centre and Sub-Centre Chairmen's Addresses
February 1955	A. E. GUILE, PH.D., B.SC.(ENG.) **The Effects of Pre-Loading on Fuse Performance** (PAPER No. 1775 U)
March 1955	A. R. MOSS **Characteristics of the Molybdenum-Depositing Arc and the Metal-Arc Melting Process** (PAPER No. 1768 U)
Digest not yet published	B. SCHWARZ, D.SC.TECH., DIPL.ING. **The Theory and Application of a Self-Propelled Stator-Fed Frequency Convertor** (PAPER No. 1766 U)
	Written discussion on **The Damage to Lead-Sheathed Cables by Rodents and Insects**
February 1955	T. H. BARTON, PH.D., B.ENG., AND B. C. DOXEY, B.ENG. **The Operation of Three-Phase Induction Motors with Unsymmetrical Impedance in the Secondary Circuit** (PAPER No. 1784 U)
	Discussion on **The Control of a Thermal Neutron Reactor** before the North Staffordshire Sub-Centre

DATE OF JOURNAL DIGEST OR SPECIAL ARTICLE

PART A. POWER ENGINEERING (FEBRUARY, 1955) (*contd.*)

Digest not yet published
R. L. RUSSELL, M.SC.
The Application of Symmetrical Components to the Measurement of Phase Difference in Single-Phase Circuits (PAPER NO. 1758 M)

Digest not yet published
R. L. RUSSELL, M.SC.
The Determination of Phase Rotation of Polyphase Systems (PAPER NO. 1789 M)

Discussion on **The Electrolytic Analogue in the Design of High-Voltage Power Transformers** before the South-East Scotland Sub-Centre, the Mersey and North Wales Centre, the North-Western Centre and the South Midland Supply and Utilization Group

Written discussion on **Impulse Puncture Characteristics of Mass-Impregnated Paper-Insulated Cables, with special reference to Testing Procedures**

Discussion on **The First Stage of the Electrification of the Estrada de Ferro Santos a Jundiai** before the East Midland Centre and the North-Eastern Centre

Written discussion on **A High-Frequency Simulator for the Analysis of Power Systems**

Digest of an Institution Monograph:

A. N. INCE, B.SC.
The Design of Coils for the Production of High Magnetic Fields (MONOGRAPH NO. 102)

PART B. RADIO AND ELECTRONIC ENGINEERING (MARCH, 1955)

MERVIN J. KELLY, PH.D., D.ENG., D.SC., LL.D., SIR GORDON RADLEY, C.B.E., PH.D.(ENG.), G. W. GILMAN, M.S., AND R. J. HALSEY, B.SC.(ENG.)
January 1955
A Transatlantic Telephone Cable (PAPER NO. 1741, SEPTEMBER, 1954)

Discussion on **Post-Graduate Activities in Electrical Engineering** before the North Midland Centre, the South Midland Centre, the Southern Centre, and the North-Eastern Centre

Local Centre and Sub-Centre Chairmen's Addresses

Discussion on **A Survey of Electrical Ceramics** before the South-West Scotland Sub-Centre

J. MCA. STEELE, B.SC.(ENG.)
February 1955
The Standard Frequency Monitor at the National Physical Laboratory (PAPER NO. 1765 M, OCTOBER, 1954)

Digest not yet published
H. B. LAW, B.SC.TECH.
Standard Frequency Transmission Equipment at Rugby Radio Station (PAPER NO. 1762 R, OCTOBER, 1954)

Discussion on the **above two papers** and on **Standard Frequency Transmissions** before the Radio and Measurements Sections

PROFESSOR H. E. M. BARLOW, PH.D., B.SC.(ENG.)
February 1955
The Application of the Hall Effect in a Semi-Conductor to the Measurement of Power in an Electromagnetic Field (PAPER NO. 1654 M, JUNE, 1954)

PROFESSOR H. E. M. BARLOW, PH.D., B.SC.(ENG.)
February 1955
The Design of Semi-Conductor Wattmeters for Power-Frequency and Audio-Frequency Applications (PAPER NO. 1778 M, NOVEMBER, 1954)

A. H. M. ARNOLD, PH.D., D.ENG.
February 1955
Audio-Frequency Power Measurements by Dynamometer Wattmeters (PAPER NO. 1653 M, APRIL, 1954)

Discussion on the **above three papers** before the Measurements Section

Digest not yet published
N. L. YATES-FISH, M.A., D.PHIL., AND E. FITCH, B.SC.
Signal/Noise Ratio in Pulse Code Modulation (PAPER NO. 1776 R)

Digest not yet published
W. A. JOHNSON, M.A.
The Notch Aerial and some Applications to Aircraft Radio Installations (PAPER NO. 1742 R)

Digest not yet published
A. F. HARVEY, D.PHIL., B.SC.(ENG.)
A Surface-Texture Comparator for Microwave Structures (PAPER NO. 1756 R)

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A. F. HARVEY, D.PHIL., B.SC.(ENG.)
The Electroforming of Components and Instruments for Millimetre Wavelengths (PAPER NO. 1757 R)

Digest not yet published
E. F. STACK-FORSYTH, B.SC., PH.D.
An Experimental Study of the Propagation of 10cm Radio Waves over a Short Non-Optical Sea Path (PAPER NO. 1780 R)

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G. J. RICH, M.SC.
The Launching of a Plane Surface Wave (PAPER NO. 1783 R)

Digest not yet published
A. E. BARRINGTON, PH.D., B.SC.
Cold Measurements of 8mm Magnetron Frequency and Pulling Figure (PAPER NO. 1792 R)

Discussion on **Printed and Potted Electronic Circuits** before the South Midland Radio Group

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PART B. RADIO AND ELECTRONIC ENGINEERING (MARCH, 1955) (*contd.*)

Discussion on **Electronic Telephone Exchanges** before the Mersey and North Wales Centre

J. ALLISON, B.SC.(ENG.), AND F. A. BENSON, M.ENG., PH.D.
Surface Roughness and Attenuation of Precision-Drawn, Chemically Polished, Electropolished, Electroplated and Electroformed Waveguides (PAPER NO. 1785 R)

Digest not yet published

Written discussion on **Reception of an F.M. Signal in the Presence of a Stronger Signal in the same Frequency Band, and other Associated Results**

Digests of Institution Monographs:

J. M. C. DUKES, M.A.
The Effect of Severe Amplitude Limitation on certain types of Random Signal: a Clue to the Intelligibility of "Infinitely" Clipped Speech (MONOGRAPH NO. 111 R)

J. L. FARRANDS, PH.D., B.SC.
The Generation of Millimetre Waves (MONOGRAPH NO. 112 R)

PART C. MONOGRAPHS (MARCH, 1955)

Digests of Monographs are not published in the Journal

Written discussion on **The Transient Response of R.F. and I.F. Filters to a Wave Packet**

J. K. WEBB, M.SC.ENG., B.SC.TECH., AND H. B. WOOD
The Precise Measurement of Capacitance (No. 100 M)

S. E. YUSSUF, PH.D., AND PROFESSOR J. C. PRESCOTT, D.ENG.
The A.C. Impedance of Plasma Discharges in Mercury Vapour (No. 101)

A. N. INCE, B.SC.
The Design of Coils for the Production of High Magnetic Fields (No. 102 M)

JANET RIDDLESTONE, B.A.
The Variation with Current and Inductance of Metal Transfer between Platinum Contacts (No. 103)

D. G. LAMPARD, M.SC.
A New Method of Determining Correlation Functions of Stationary Time Series (No. 104 R)

A. W. BRIGHT, PH.D., B.SC.(ENG.), AND H. C. HUANG, PH.D., B.SC.(ENG.)
Formative Time-Lag Studies with High-Frequency Discharges (No. 105 R)

W. E. THOMSON, M.A.
The Response of a Non-Linear System to Random Noise (No. 106 R)

C. B. SPEEDY, PH.D., B.E.
The Function of Basic Elements in Digital Systems (No. 107 M)

M. W. ALLEN, B.E.
A Beam-Deflection Valve for use in Digital Computing Circuits (No. 108 M)

R. H. EVANS, B.SC.
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A. J. O. CRUICKSHANK, B.SC., PH.D.
A Note on Time Series and the use of Jump Functions in Approximate Analysis (No. 110 M)

J. M. C. DUKES, M.A.
The Effect of Severe Amplitude Limitation on certain types of Random Signal: a Clue to the Intelligibility of "Infinitely" Clipped Speech (No. 111 R)

J. L. FARRANDS, PH.D., B.SC.
The Generation of Millimetre Waves (No. 112 R)

D. B. BRICK, PH.D., S.M., A.B.
The Radiation of a Hertzian Dipole over a Coated Conductor (No. 113 R)

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